CAUSES, WASTE COMPOSITIONS, AND WASTE VOLUMES ASSOCIATED WITH INTEC TANK FARM SOIL CONTAMINATION SITES CPP-15 AND -79 DEEP

Summary

A recent remedial investigation/feasibility study work plan (Reference 1) describes the soil contamination sites in the Idaho Nuclear Technology and Engineering Center (INTEC) Tank Farm. The work plan describes the configuration of the system from which the contamination was released, the estimated amount of material released to the soil, and the Cs-137 and Sr-90 activity of the contamination that was released to the soil. Much of the information in the work plan was documented in previous reports and studies. However, the work plan makes different assumptions from historical documents for some of the waste compositions or amounts of waste that leaked. For some of the sites, such as CPP-79 deep, very little historical information is available. This document provides a detailed description of two of the contaminated soil sites (CPP-15 and -79 deep) in the work plan. Current groundwater investigations and modeling requires additional information such as the Tc-99 and I-129 activity and nitrate content of the releases that is not in the recent work plan or in historical reports. This report provides estimates of such data. Some of the work plan data were based on very conservative assumptions for the amount of waste that leaked. For groundwater modeling calibration purposes, more realistic values are needed. This report provides more refined estimates to be used for ground water modeling purposes.

Site CPP-79 Deep

Overview of CPP-604 Waste Tank System Configuration and CPP-79 Leak

Site CPP-79 is a medium-sized area north of the CPP-604 tank vault. Reference 1 indicates CPP-79 was contaminated by leaks from two different sources at two different elevations; a known source consisting of PEW Evaporator feed solution caused low-activity contamination in a shallow area, and a second, unknown source created high-activity contamination in an area further below grade. Reference 2 describes in detail the events and information associated with the leak of PEW Evaporator feed solution and the contamination of the shallow portion of CPP-79. That information is not repeated here. This report focuses on the contamination in the deeper portion of the site whose source was unknown at the time Reference 1 was written.

Recent (2004) soil sample analyses also detected a second layer of contamination in the CPP-28 site, below the depth of that site's historically described (relatively shallow) contamination zone. As described in Reference 1, the deep contamination in CPP-28 is not associated with the shallow contamination. The CPP-28 deep contamination is at the same elevation (about 30 feet below the surface of the Tank Farm) as the deep contamination in CPP-79. Sites CPP-20 and CPP-79 are near each other. The piping system responsible for the CPP-79 deep contamination had a tile encasement that likely leaked in multiple locations. That piping system ran within 5 feet of the CPP-28 borehole location where the deep contamination was found, and likely caused that contamination as well. Therefore, references to the CPP-79 deep contamination source term, volume of waste released, etc, in this report also apply to the CPP-28 deep contamination.

There are no historical reports documenting the leak(s) that caused the CPP-79 deep contamination. It was discovered during the 1990s Tank Farm upgrade project and recent soil sampling activities. The contamination scenario described in this report is based upon an evaluation of historical operating data, equipment configuration, recent contaminated soil sample analyses, and process knowledge. The contamination at CPP-79 deep likely occurred during three waste transfers from the CPP-604 tanks to the Tank Farm during 1967 (one transfer) and 1973 (two transfers). During those transfers, waste leaked from failed flange gaskets in valve boxes A3A and A3B. Some of that waste entered split tile pipe encasements that penetrated the bottoms of the valve boxes. The waste leaked from the tile encasements into the soil in a nearly horizontal portion of the piping located about 30 feet below the surface of the Tank Farm, causing the CPP-79 deep contamination site. The leaks went unnoticed because they were too small to have been detected by the waste monitoring systems that existed at the time.

There are no historical records that identify the leaks that contaminated the CPP-79 and CPP-28 deep areas. Therefore, this report provides a considerable amount of detail regarding the design and configuration of the CPP-604 tank and piping system, the historical use of that system, and the 2004 contaminated soil sample data so the reader will understand the basis for the estimates of the amount of waste leaked and its source term.

CPP-604/Tank Farm Piping Configuration and Leakage Path

In order to understand the basis for the estimate of the leaks that caused the CPP-79 deep contamination, some knowledge of the configuration and history of the CPP-604 waste tanks is necessary. The original configuration of the high-level (first-cycle) liquid waste storage system included three 18,000-gallon tanks (WM-100, -101, and -102), which were located in two underground tank vaults on the north end of CPP-604. High-level waste was sent from the fuel reprocessing building (CPP-601) to the three CPP-604 waste tanks for interim storage before being transferred to the large, 300,000-gallon storage tank WM-180. Stainless steel waste transfer lines encased in split tile pipe were used to transfer waste from the CPP-604 tanks to WM-180.

Due to its early success, the spent nuclear fuel reprocessing program and its associated waste storage system were expanded. A major project was completed in 1955 that installed three new 300,000-gallon waste storage tanks (WM-182, WM-183, and WM-184) and three new valve boxes (A2, A3A, and A3B) north of CPP-604. The new valve boxes connected the original CPP-604/Tank Farm waste transfer lines to the three new tanks. The new configuration continued to use the original waste transfer system that sent waste from CPP-601 to the CPP-604 tanks, and from the CPP-604 tanks to the 300,000-gallon tanks. Figure 1 shows the configuration of some of the transfer lines and valve boxes associated with the CPP-604 tanks.

Figure 1 shows two tile encased lines (colored orange) that exit the north end of the CPP-604 tank vault. The westernmost tile-encased line in Figure 1 came from WM-102. The line exited the vault nearly 30 feet below the Tank Farm surface, turned, and ran vertically to near the Tank Farm surface elevation where valve box A3A was located. The line then went back down to its original elevation 30 feet below the Tank Farm surface, turned, and went to WM-180. Another piping system (not shown on Figure 1) was located about 20 feet west of the WM-102 transfer piping system. That system was identical to that of WM-102 and contained the WM-101 discharge piping and valve box A3B. The convoluted piping system (long, u-shaped, vertical loop) was part of the original design and provided relatively easy access to the piping to make future connections, such as occurred in 1955.

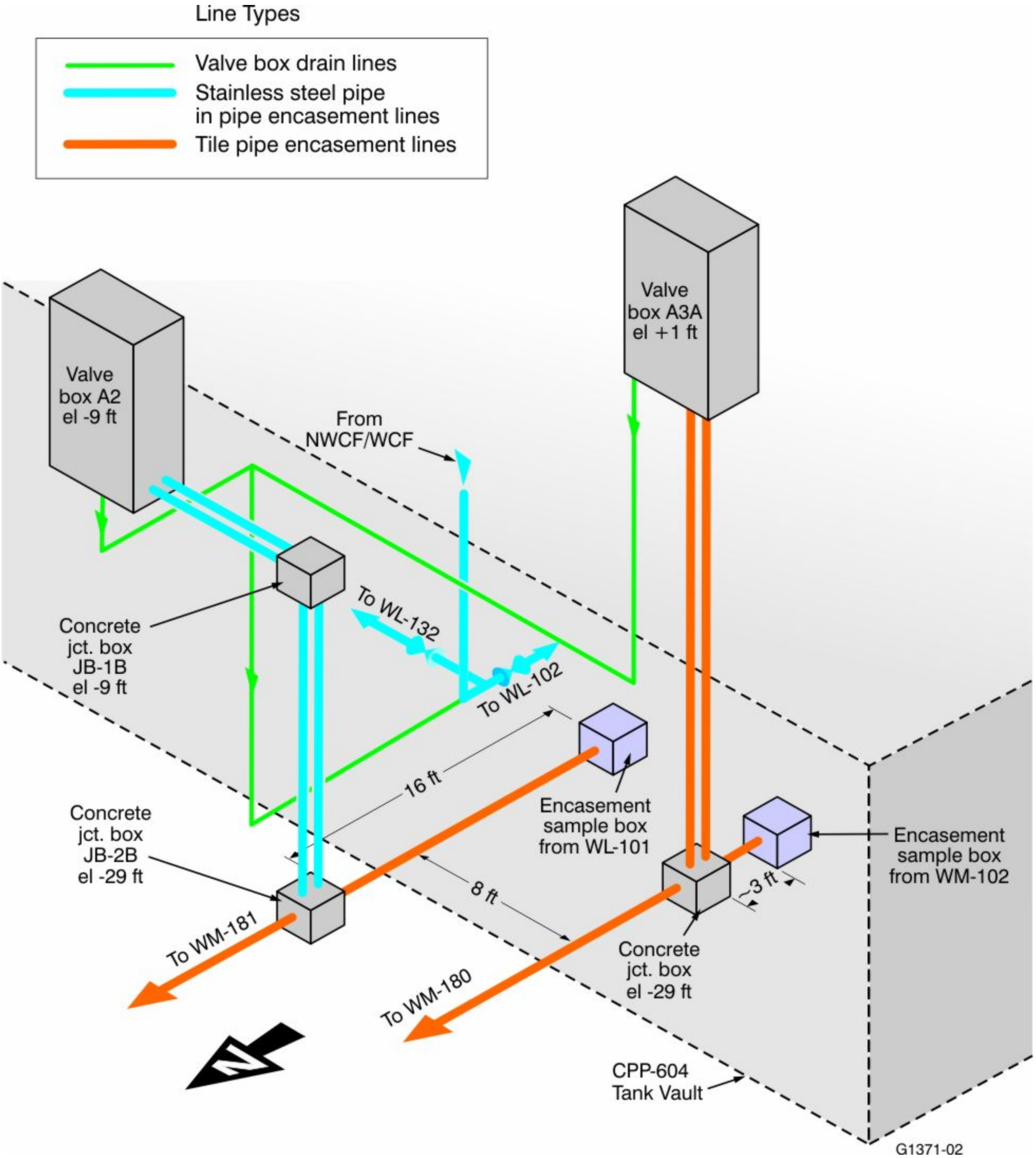

Figure 1. Schematic showing the configuration of waste transfer piping and valve boxes near the CPP-604 tank vault associated with site CPP-79 and CPP-28 deep contamination.

Valve boxes A3A and A3B were not part of the original design but were added in the 1955 expansion project. They were constructed on top of the original transfer lines, with the original lines entering and exiting the bottom of the valve box. Additional lines (not shown on Figure 1) penetrated the sides of the valve boxes and went to the new tanks. The valve boxes were equipped with a stainless steel drip pan (liner) with a drain line that led to the PEW Evaporator feed collection tank, WL-102 (see Figure 1). The valve box liner was not welded or connected to the transfer piping that entered/exited the bottom of the valve boxes. Instead, the liner had a collar, or lip, 2-3 inches high, that surrounded the lines where they penetrated the bottom of the valve box. This configuration was designed to collect leaking solution in the drip pan and direct it to WL-102.

The piping configuration of valve boxes A3A and A3B, with their tile-encased lines entering and exiting the bottom of a valve box, was unique to a handful of valve boxes installed with the 1955 Tank Farm upgrade and led to the CPP-79 deep contamination. Waste leaked from valve flanges in boxes A3A and A3B due to deteriorated flange gaskets. By design, the leaking waste should have been collected in the stainless steel liner that drained into WL-102. However, two situations allowed some leaking waste to exit the box via the tile pipe encasements that penetrated the bottom of the valve box. A plugged drain line in box A3A caused leaking solution to collect in the box liner until it overflowed the collar surrounding the transfer lines and flowed into the tile encasements that entered the bottom of the valve box. In addition, some of the leaking solution in A3A and A3B likely fell directly into the annular gap between the transfer line and the collar surrounding the transfer line because the leaking valves were above the penetrations in the valve box floor. In these two ways, leaking waste left the valve boxes and entered the tile encasements entering the floor of the valve boxes.

Once inside the tile encasements, the leaking solution fell about 30 feet into a nearly horizontal portion of the encasements that ran north and south between CPP-604 and WM-180. The tile encasements were designed to drain to a sample box (shown on Figure 1) located on the north end of the CPP-604 tank vault. The sample box had a drain line that went into the stainless-steel lined CPP-604 tank vault where it could be detected. Construction of valve boxes A3A and A3B in 1955 on top of the original transfer lines may have caused dirt or other construction debris to fall into the tile encasements and plug the encasement drain lines leading into the CPP-604 tank vault. This compromised the leak detection system and caused the liquid in the encasements to leak from the encasements into the soil instead of draining into the CPP-604 tank vault.

The tile encasements were not a superior design. The tile pipe was brittle and susceptible to cracking due to soil settling. In addition, the caulking used to seal the tile pipe joints was not resistant to nitric acid, a primary component of Tank Farm waste. The 1955 project excavated the area north of CPP-604 near the lines associated with box A3A. That project installed the junction box (JB-2B) shown on the tile encased line leading to tank WM-181 (see Figure 1). Such construction in close proximity to tile encased lines likely resulted in some soil settling and subsequent cracking of the tile encasements.

The tile encasements may have had more than one crack and potential leakage points along their paths. Waste leaking into the tile encasements likely traveled several feet in the near-horizontal section of piping nearly 30 feet below grade and leaked from several points. The transfer line from WM-102 ran north from CPP-604 through the areas covered by sites CPP-79 and CPP-28. Leakage from several locations along this path resulted in the deep contamination layers found in both CPP-79 and CPP-28. Alternatively, leakage from a single point could have been conducted via the sand bed used beneath the transfer lines several feet from the original leak location and contaminated areas within both CPP-79 and CPP-28.

CPP-604 Piping Use and Leakage Period Determination

Because there are no historical reports of the leak(s) that caused the CPP-79 deep contamination, estimates of the number of leaks that occurred and the volume of waste that leaked were made. This required an evaluation of the frequency of use of the CPP-604 waste transfer system, the types of waste it stored, etc.

During the early and mid 1950s the only waste route into the 300,000 gallon tanks was via the CPP-604 tanks and their associated piping. Consequently, the CPP-604 tank piping was regularly used for waste transfers during that time period. Steam-powered jet pumps provided the motive force to transfer waste from the CPP-604 tanks to the 300,000-gallon tanks. The jet pumps had no moving parts and thus needed no maintenance, an advantage in a radioactive environment. However, use of the jets added steam condensate to the waste, which increased the volume of the waste by approximately 10% for transfers made from the CPP-604 tanks. This was a significant disadvantage because it effectively added water to the limited Tank Farm storage space. Efforts were made to reduce the steam jet water to better use the limited Tank Farm storage space.

Accordingly, in October 1957, another major plant expansion project was completed that built two more 300,000-gallon waste tanks (WM-185 and -186) and a new waste transfer system. The new waste transfer system bypassed the CPP-604 tanks and their steam jets. The new system transferred waste directly from CPP-601 to the Tank Farm using an airlift (WM-178), which eliminated steam jet dilution. Thereafter, the airlift was used for the bulk of waste transfers from CPP-601 to the Tank Farm. The CPP-604 tanks were used on a limited basis, to segregate special types of wastes (such as ROVER), or when the transfer lines in the Tank Farm were out of service (such as during valve maintenance), etc.

Identifying the type of waste that leaked to the soil and correlating it with the fuel reprocessing and waste generation history of INTEC helped identify the leaks that caused the CPP-79 deep contamination. During its history, INTEC reprocessed a variety of spent nuclear fuels. Different types of fuel generated chemically unique wastes due to differences in fuel cladding and the chemicals used in dissolving and reprocessing the different types of fuels. Detecting (or the failure to detect) these unique chemicals in the contaminated soil helped identify the source of waste and time of the leak.

Prior to 1966, virtually all waste sent to the CPP-604 or the 300,000-gallon tanks came from reprocessing aluminum (Al)-clad fuel. In the mid 1960s, reprocessing of large quantities of zirconium (Zr)-clad fuel began (Al fuel reprocessing also continued). Moderate amounts of stainless steel-clad fuel were reprocessed in the 1970s and early 1980s. Beginning in the early 1970s, most of the Zr and Al-clad fuels were reprocessed in a “coprocessing” system that was designed to minimize waste generation. Coprocessing dissolved both Al and Zr-clad fuels and combined the two dissolver products for subsequent uranium recovery. Each of these processes produced chemically unique wastes. For example, mercuric nitrate was used as a catalyst to dissolve Al-clad fuel. Thus, mercury (Hg) was found in Al waste but not in Zr or stainless steel wastes. Waste from Zr fuel reprocessing contained Zr from the cladding material and fluoride (F) from the hydrofluoric acid used to dissolve the Zr cladding. Neither Al nor stainless steel wastes contained Zr or F. Because coprocessing waste was a combination of both Zr and Al wastes, it contained Hg, Zr, and F. The fission product content of most first-cycle wastes was similar (especially in old waste in which short-lived species had decayed), but there were differences among activation products such as the transuranic (TRU) components. For example, Al waste had a moderate Pu-238:Pu-239 ratio (ranging between 3 and 10). Zr waste had a much higher (over an order of magnitude) Pu-238:Pu-239 ratio than Al waste. Stainless steel waste had a much lower Pu-238:Pu-239 ratio (over an order of magnitude) than Al waste. These unique chemical species and radionuclide ratios helped identify the sources of leaks in CPP-79 deep, based on the 2004 soil sample analyses.

Figures 2 and 3 show the volume and type of waste stored in WM-101 and WM-102 respectively between May 1965 and January 1980, the time in which the CPP-79 deep contamination occurred. The waste volume varied between 0 to 18,000 gallons as the tanks were filled and emptied over time. The areas beneath the volume curves are colored to show the volume and type of waste in the tanks. Figures 2 and 3 do not include data for WM-100. During the 1955 expansion project, only the transfer lines from WM-101 and WM-102 were connected with the new portion of the Tank Farm, leaving WM-100 connected only to WM-180. As a result, waste from WM-100 was never transferred directly to the Tank Farm during the suspected leak period. Instead, waste was transferred from WM-100 to WM-102, and from there to the Tank Farm.

Figures 2 and 3 each contain two dashed lines, one in 1966 and one in 1974, with text boxes indicating leaks did not occur before or after those dates. The reasons for this are as follows. In October 1974, contaminated soil associated with site CPP-28 (shallow) was discovered in an area north of CPP-604. Operations personnel conducted an exhaustive search for the cause of the CPP-28 contamination. One of the potential contamination sources was the waste transfer lines and encasements from valve boxes A3A and A3B. Those two valve boxes were excavated and inspected to determine if they had contributed to the CPP-28 contamination. The inspection found those boxes had not caused the CPP-28 contamination. However, the inspection found 1-2 inches of standing liquid in the stainless steel liner of box A3A with a radiation field of over 25 R/hr. No standing liquid was observed in box A3B. The drain line in box A3A was plugged (accounting for the standing liquid in A3A), whereas the A3B drain line was clear. Inspection of the flanged valves in each box found the Teflon gaskets “in a high state of deterioration” (Reference 3). Gaskets made of Teflon fail and leak in radiation environments because Teflon becomes brittle and cracks after extended exposure to radiation. The valves were removed, refurbished, and reinstalled with gaskets that were not subject to radiation damage. The deteriorated state of the gaskets and the standing radioactive solution in box A3A indicates leaks occurred in the valve boxes prior to October 1974.

No leaks from A3A or A3B are believed to have occurred after 1974. The new, radiation-resistant valve gaskets prevented gasket-related leaks thereafter. The Tank Farm waste monitoring and leak detection capabilities were significantly improved after 1974. The improved monitoring systems have shown no evidence of leaks from that piping system. The relative ratios of the radionuclides in the 2004 contaminated soil samples indicate that the leaked waste was relatively old. Radioactive waste contains both Cs-137 (half life equal to 30 years) and Cs-134 (half life equal to 2.1 years). The ratio of Cs-137/Cs-134 increases at a known rate over time due to the rapid decay of Cs-134. That ratio can be used to estimate the age of a waste. The Cs-137 activity in the CPP-79 deep contamination layer (32-36 ft below surface) was about 3×10^6 pCi/g. The Cs-134 activity in all the deep contamination sites was below the laboratory detection value. For the cited CPP-79 location, the Cs-134 detection value was 212 pCi/g. Use of the Cs-134 detection value results in a Cs-137/Cs-134 ratio of over 15,000. This ratio is high enough to indicate the waste in the soil came from fuel reprocessed before the 1980s, not from more “recent” waste. These data, along with the 1974 valve gasket repairs, indicate 1974 was the latest date at which leaks occurred from the CPP-604 piping system. This is shown as a dashed line on Figures 2 and 3.

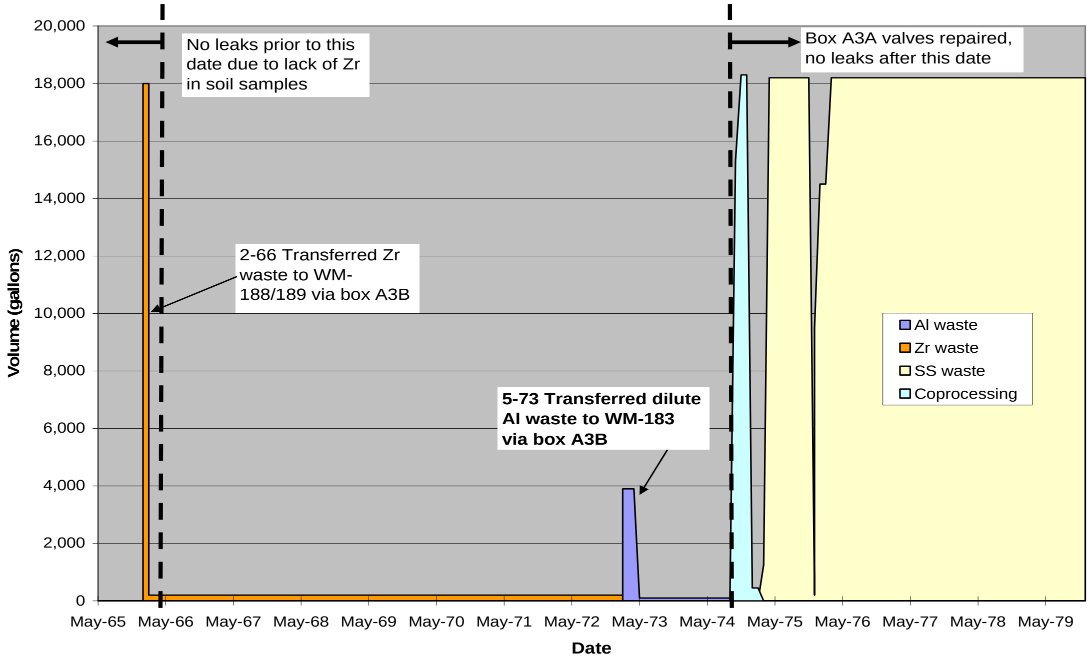

Figure 2. Volume and type of waste stored in WM-101 from May 1965 through December 1979.

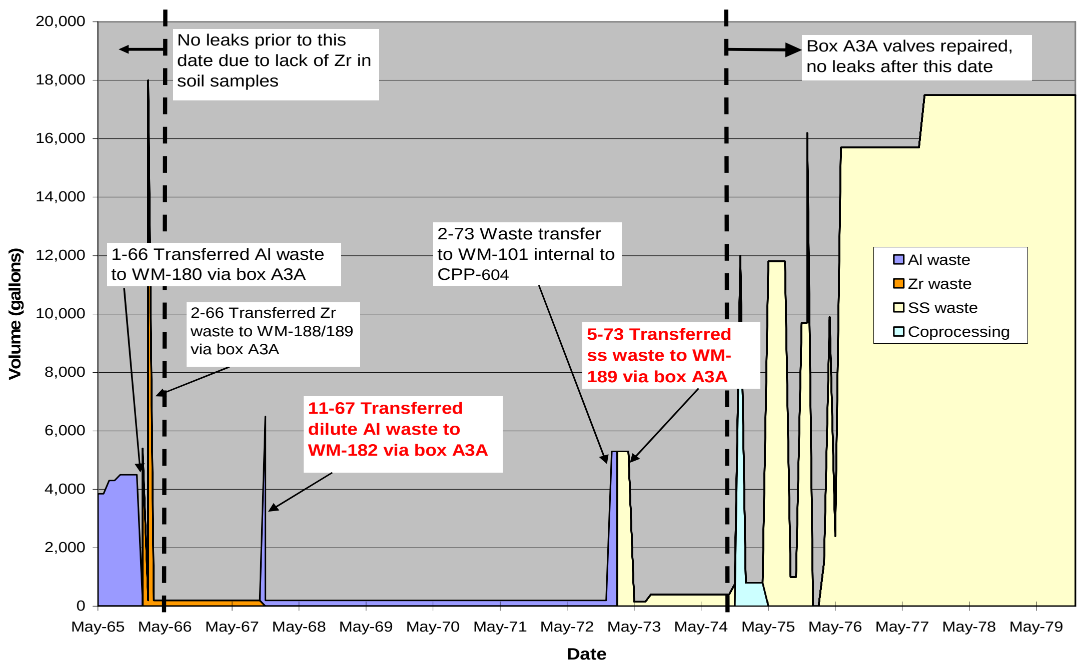

Figure 3. Volume and type of waste stored in WM-102 from May 1965 through December 1979.

Valve boxes A3A and A3B (with their original Teflon gaskets) were installed in the 1955 upgrade project. The 1955 project excavated into the CPP-79 deep contamination area, but there are no reports of any contaminated soil found during that project. Therefore, the contamination occurred after that time. Although Teflon gaskets fail over time in high radiation environments, they likely lasted several years before the damage was so severe that waste leakage occurred. After 1957, when the airlift transfer system was installed, transfers out of the CPP-604 waste tanks occurred very infrequently, as shown on Figures 2 and 3. The infrequent use limited the number of potential leaks from the system after 1957.

Contaminated soil sample and waste storage history data indicate leaks did not occur before 1966. In January 1966, maintenance work was performed on valves in box A6 during a Zr fuel reprocessing campaign. Box A6 is the junction point for the transfer route from CPP-601 to the Tank Farm. All waste sent to the Tank Farm from CPP-601 via the air lift traveled through box A6. Fuel reprocessing operations were not stopped in January 1966 to repair the valves in box A6. Instead, the Zr waste was sent to the three CPP-604 tanks for interim storage while the valves in box A6 were repaired. The Zr waste was transferred from the CPP-604 waste tanks to the Tank Farm when the valve maintenance was complete. Figures 2 and 3 show this as an increase in the Zr waste inventory in the CPP-604 tanks (the very narrow orange band in 1966), followed by a reduction to near zero when the waste was transferred to the Tank Farm. This was the only time prior to 1974 (when the valves inside boxes A3A and A3B were repaired) that the CPP-604 tanks held Zr waste.

Several of the CPP-28 and CPP-79 soil samples were analyzed for Zr. Neither Cs-137 nor Zr is very mobile in soils. If any of the Zr waste leaked during the 1966 waste transfer, it would have created high levels of both Cs-137 and Zr in the contaminated soil. On the other hand, if the 1966 Zr waste did not leak, there would be no elevated levels of Zr in the contaminated soil. The deterioration of the Teflon valve gaskets was progressive with time. If the 1966 Zr waste transfers did not leak from the valves in boxes A3A and A3B, then waste transfers made before that time would not have leaked because the valve gaskets would have been in better condition during earlier transfers. Thus the presence or absence of Zr in the contaminated soil can be used to establish leak dates.

In the late 1960s and early 1970s, typical Zr waste contained about 1×10^{12} pCi/L (1 Ci/L) Cs-137 and 37,000 mg/L (0.4 M) Zr. Decaying the Cs-137 in the 1966 Zr waste to the present time (38 years) leaves about 42% of the original Cs-137 remaining today, or 0.42×10^{12} pCi/L. The Zr:Cs137 ratio of the 1966 Zr waste would be 8.8×10^{-8} mg Zr/pCi Cs-137 if measured today. This would be the Zr/Cs-137 ratio in the CPP-79 deep contamination if it contained 1966 Zr waste. The Cs-137 activity from the 2004 CPP-79 deep soil samples was about 3×10^{6} pCi/g of soil. Multiplying the Cs-137 activity in the contaminated soil by the Zr/Cs-137 ratio from the 1966 Zr waste (decayed to the present time) results in an expected Zr concentration of 0.260 mg per gram of soil, or 260 mg/kg. The Zr in the analyzed soil samples (from shallow and deep sites in both CPP-28 and CPP-79) ranged from 15 to 30 mg/kg and had no correlation with the Cs-137 activity. The Zr content of the contaminated soil was an order of magnitude below the value expected from Zr waste contamination and appeared to be the normal Zr content of the Tank Farm soil. In addition, Zr waste had a very high Pu-238:Pu-239 ratio (approximately 75:1). The ratio of Pu-238:Pu-239 in CPP-79 deep was approximately 1:1. Some of the soil samples even had more Pu-239 than Pu-238. Such Pu ratios did not come from Zr waste, instead they indicate the waste came from stainless-steel fuel. The contaminated soil data show the 1966 Zr waste transfer did not leak to the soil, and thus Al waste transfers prior to that time also did not leak. This accounts for the dashed line on Figures 2 and 3 in 1966 as the earliest date at which leaks occurred.

The 1974 inspection of valve boxes A3A and A3B found evidence of past leaks from valve flanges due to deteriorated Teflon gaskets. The lack of elevated Zr levels and Pu-238:Pu-239 ratios of approximately 1:1 in the contaminated soil indicate the leaks did not occur before 1966. Therefore, leaks occurred in valve boxes A3A and A3B between 1966 and 1974 (the two dashed lines on Figures 2 and 3) that led to the CPP-79 deep contamination. There were only three waste transfers from the CPP-604 waste tanks to the Tank Farm during that time period, one from WM-101 and two from WM-102. Figure 3 shows three transfers were made from WM-102, but one of them went to WM-101 through CPP-604 internal piping, not to the Tank Farm. Text boxes on Figures 2 and 3 note the three transfers that potentially leaked with red lettering.

Waste Source Term

Defining a single waste source term for CPP-79 deep from historical operating data is difficult because there were multiple leaks of varying types of waste and the relative amount of each waste type in each waste transfer is uncertain. Historical operating data show the waste that leaked definitely included first-cycle stainless-steel waste, and likely included first-cycle Al waste, second cycle waste, and process equipment waste. Each of the CPP-604 waste tanks also had a small amount of Zr waste residue from 1966 when they stored first-cycle Zr waste. The 1967 Al waste in WM-102 included second-cycle raffinate that had been recycled through the first cycle extraction system as part of a Np-237 recovery process that operated for a few years at INTEC. The 1973 Al waste in WM-101 likely included some process equipment waste (PEW) that was normally sent to the PEW Evaporator, but had been recycled through the first-cycle extraction system for uranium recovery. The second-cycle and PEW wastes had less activity than typical first-cycle raffinate. The 1973 WM-102 waste was primarily first-cycle raffinate from stainless-steel clad fuels.

Leaks of varying solutions caused the different chemical and radionuclide ratios seen in the 2004 soil samples. The 32-36 foot sample from CPP-79 contained a high amount of Hg (7.61 mg/kg), compared with the background soil concentration (0.02 mg/kg). The Cs-137 at that elevation was 3.35×10^6 pCi/g, or 3.35×10^9 pCi/kg. This yields a Cs-137/Hg ratio of 4.4×10^8 pCi/mg. Typical first-cycle Al raffinate contained about 1 Ci/L (1×10^{12} pCi/L) Cs-137 and 2000 mg/L Hg. Assuming the site is contaminated with “old” waste in which one half of the Cs-137 has decayed, the current Cs-137/Hg ratio of the waste would be 2.5×10^8 pCi/mg, which is close to that of the contaminated soil sample. Thus the contamination shows evidence of first-cycle Al waste. The deep contamination sites have elevated activities of Pu-239 compared to Pu-238. The 56-60 ft CPP-79 sample contained more Pu-239 activity than Pu-238 activity. Waste from stainless-steel fuel was the only waste that contained more Pu-239 activity than Pu-238, thus the deep contamination shows evidence of stainless steel waste. The soil contamination data correlate with the types of high-activity-wastes stored and transferred through the CPP-604 tanks in the late 1960s and early 1970s.

The information on the amount of each type of waste stored in the CPP-604 tanks in the late 1960s and early 1970s is sketchy. Instead of generating multiple radiological source terms for each of the various wastes that leaked based upon sketchy data, two source terms were developed based on the ratios of Pu-238:Pu-239/240 found in the two most highly contaminated CPP-79 soil samples, those at the 56-60 and 34-36 feet below grade surface[4]. The Pu isotope ratios varied significantly among different types of fuels (and consequently their wastes) and can be used to estimate the portion of each type of waste in a mixture of wastes.

The first source term used the Pu ratios from the 56-60 foot (below grade) soil sample. That waste had a volumetric composition of 66% first-cycle stainless steel waste and 34% first-cycle coprocessing waste. A second source term for CPP-79 deep was developed based upon the Pu ratios in the 34-36 ft (below grade) soil sample. That sample had a high Hg content, so the source term was developed for a stainless-steel/Al waste blend. The second source term had the volumetric equivalent of 62% stainless steel waste and 38% Al waste. In general, both source terms are similar because the waste mixtures were similar, both consisting of nearly 2/3 stainless steel waste. Both source terms fit the waste storage tank history with the dominance of the stainless steel waste.

For long lived fission products, the two CPP-79 source terms are virtually the same, since fission product activity is related to the age of the waste, not the type of fuel from which it was derived. However, the activation products of the two source terms vary due to differences in the types of fuels from which the waste is derived. This difference was generally a factor of 2 or less. In general, the first source term has more Co-60 and Pu-239, and the second source term has more Np and Am.

The two source terms for CPP-79 deep do not vary significantly in fission product content, and the variation in activation products is typically a factor of two or less. Without any quantitative data on the amounts of each waste type released at CPP-79 deep there is no way to reliably assign portions of the waste that leaked to either source term. Therefore, instead of arbitrarily assigning portions of the waste to each source term, this report uses the first source term (56-60 foot elevation) for all of the CPP-79 deep activity. This provides a worst-cast activity for Pu-239, which may be the most significant contaminant of concern. The activity of the major fission products of concern (based upon the 56-60 foot sample) is shown in Table 1. The source term is based upon a Cs-137 activity of 0.619 Ci/L in 1973. This Cs-137 activity is conservatively high, because it assumes all the waste was first-cycle waste. Some of the waste that leaked was PEW and second-cycle wastes, which contained less activity than first-cycle waste. Details concerning the derivation of the source term are in Appendix A.

The nitrate concentration of the CPP-79 waste varied between 3.5 and 4.5 M for the bulk of the wastes that leaked, first-cycle Al and stainless steel raffinates, as well as second-cycle waste. A value of 4.0 molar is a reasonable average for such wastes and it is included in Table 1.

Table 1. Source term for major radionuclides and nitrate in the waste released at CPP-79 deep.

Cs-137	**Sr-90**	**H-3**	**Tc-99**	**I-129**	**NO_3**
0.62 Ci/L	0.58 Ci/L	3.5 mCi/L	0.099 mCi/L	0.24 microCi/L	4.0 Molar

Waste Volume Leaked

A detailed review of the waste transfers that potentially leaked (see Figures 2 and 3) resulted in an estimated release of 400 gallons of waste. This estimate is at the lower end of the range of the estimate made in Reference 1. It is fairly certain the release was small (a few hundred gallons) because there were very few transfers that potentially leaked and the transfers were small (which limited the potential leakage). The leaked volume was not large enough for a volume discrepancy to have been noted in any historical reports. Calculations and assumptions for the release volume estimates are in Appendix A of

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[4] D. R. Wenzel internet memo to M. C. Swenson dated February 9, 2005 titled “CPP-79 Source Term”, and D. R. Wenzel internet memo to M. C. Swenson dated February 13, 2005, titled “CPP-79 Source Term for 34-36 foot depth”. Both memos to be formally documented in the future.

this report. The calculations assume the average jet dilution for first-cycle waste transfers from CPP-604 to the Tank Farm was 10%. The difference between the average (10%) jet dilution and the measured value is the estimate of the waste released. For example, if 1000 gallons of waste were transferred, 100 gallons was the expected (10%) jet dilution. If the transfer data showed the jet dilution was only 70 gallons, then the assumed leak was 30 gallons. Due to variability in the jet dilution, the CPP-79 leaks could have been a few hundred gallons more or less than the 400-gallon estimate. The volume estimate is probably accurate to within a factor of 50%.

Steam jet dilution varied depending on parameters such as steam pressure, waste density, piping configuration, etc. The 1966 transfers of Zr waste from CPP-604 to the Tank Farm did not leak and had an average jet dilution of 10% (see calculations in Appendix A). The 1966 Zr waste transfers had similar characteristics (solution density, piping configuration, etc.) to those that leaked. This provides confidence in use of the 10% jet dilution factor to estimate the release. Although the leak estimate has considerable uncertainty, it is reasonably certain that the leaks were a few hundred (not thousand) gallons.

CPP-79 Summary

CPP-79 has two areas of contamination, a shallow and deep area. The shallow, low-activity leak was discussed in a previous document (Reference 2). The source of the deeper contamination was determined by a review of historical operating data, piping configurations, and 2004 contaminated soil data to have been leaks from failed valve flange gaskets in boxes A3A and A3B in the 1960s and 1970s. Some of the leaking solution went into the tile pipe encasements that penetrated the floors of the valve boxes and fell into a nearly horizontal portion of encasement approximately 30 ft below the Tank Farm surface. The waste leaked into the soil through cracks and joints in the tile encasements. The tile encasements likely leaked at multiple locations along its north/south run and thus contaminated the deep area in both the CPP-79 and CPP-28 sites.

Table 2 summarizes the activity of the major radionuclides and mass of nitrate released at site CPP-79 deep, assuming a release of 400 gallons of waste with the source term given in Table 1.

Table 2. Major radionuclides and nitrate released at CPP-79 deep from three releases totaling 400 gallons of waste.

	Cs-137	**Sr-90**	**H-3**	**Tc-99**	**I-129**	**NO_3**
CPP-79 Deep	940 Ci	870 Ci	5.3 Ci	0.15 Ci	3.6×10^{-4} Ci	380 kg

Nearly 1000 Ci of Cs-137 was released at site CPP-79 deep. Although this represents a significant release of radioactivity, it is a relatively small portion (less than 10%) of the entire Tank Farm source term, which includes nearly 17,000 Ci of Cs-137 at site CPP-31. Thus some uncertainty in the estimates of activity for CPP-79 deep should not significantly impact groundwater models.

Site CPP-15

Background of system configuration and leak

Site CPP-15 is a small site located a short distance southwest of the main INTEC exhaust stack (CPP-708) and is associated with the operation of the solvent burner system. The uranium recovery system in CPP-601 was based on solution chemistry and species solubility. The uranium extraction system mixed the aqueous fuel dissolver product, which contained both uranium and radioactive fission products, with an immiscible organic (solvent) solution. By controlling the chemistry of the solutions, the uranium was extracted from the aqueous phase into the organic phase, leaving the bulk of the fission products in the aqueous solution. The uranium-bearing organic solution was separated from the fission product-bearing aqueous solution and mixed with a new aqueous stream. By changing the solution chemistry, the uranium was extracted from the organic into the new aqueous solution. The net result was two aqueous solutions, one with the bulk of the fission products (which became first-cycle raffinate) and one with the recovered uranium. The organic solution was recycled and used over and over to extract the uranium from the aqueous dissolver product and transfer it to the new aqueous solution.

For most of the fuel reprocessing history, the organic solution used in the first-cycle extraction system was a high grade of kerosene containing about 5% tributyl phosphate (TBP). The second and third cycle uranium purification systems were similar to the first-cycle system, but used hexone as the organic. Over time, the first-cycle organic solution degraded due to radiation and collected impurities that hampered uranium recovery. As a result, the organic was periodically replaced. The used organic was sent to an underground, interim storage in tank, LE-102, located a few feet south west of the main INTEC stack (CPP-708). Periodically, the waste organic was pumped out of LE-102 and burned in a furnace that exhausted to the main INTEC exhaust stack. The hexone used in second and third cycle did not accumulate degradation products as the first-cycle organic did, and never needed replacing. Hence the solvent burner was used only for first-cycle organic raffinate, not for hexone.

Use of the solvent burner ceased in the early 1980s when a new organic waste collection system (NCE-184, -185 and -186) was built and the organic solution was burned in the Calciner as supplemental fuel for the kerosene normally burned by the Calciner to generate process heat.

There was a possibility that some water could be transferred from CPP-601 to LE-102 along with the waste organic. Should this occur, an aqueous transfer line could remove water from the bottom of LE-102 and send it to the PEW Evaporator feed collection tank, WL-102. That transfer line connected to the gravity drain line from the bottom of the INTEC exhaust stack. In March 1974, construction of a new PEW Evaporator cell on the east side of CPP-604 was underway. That project cut the stack drain line, which ran through the construction area, in order to facilitate construction activities. Valves were installed and closed on each end of the cut drain line during construction work. A hose connected the two ends of the drain line when construction was not in progress, and the valves were opened to allow liquid in the stack to drain to WL-102.

In March 1974, the drain valves remained closed too long and allowed condensate to collect in the base of the stack. The condensate went down the stack drain line and then backed up into the waste organic storage tank, LE-102, via its aqueous removal line that connected to the stack drain line. As condensate from the stack filled LE-102, the waste organic level rose until it spilled out of a flange on a tank manway that came to the surface in the small solvent storage building CPP-629. The organic waste ran across the concrete floor of the building and out onto the ground, resulting in the contamination at site CPP-15. The incident is documented in a Significant Operating Occurrence Report (Reference 5). Cleanup (removal) of the near-surface contamination occurred immediately after the event. Additional cleanup occurred in the mid 1980s when the waste solvent burner and LE-102 were removed.

Waste Source Term

The release at CPP-15 likely involved two separate source terms, one for the organic and one for the aqueous portion of the release. Reference 5 indicates the 2000-liter solvent tank was partly full prior to the incident. The event likely added enough condensate to the tank to force all of the organic to spill out of the tank, followed by some aqueous overflow as well. The organic phase was low in fission products, but relatively high in TRU activity, based on process chemistry and historical sample data. This was because the actinides (Pu, Np, Am etc.) had a solution chemistry similar to that of uranium, and a higher portion of those species (compared to the fission products) were extracted from the dissolver product into the organic during the first cycle extraction process. Thus the organic waste had a significantly different radionuclide source term than Tank Farm and other aqueous wastes. The waste organic had a very low gamma activity (fission products), but a high alpha activity (TRU components). Reference 6 provides a source term for the major constituents of the waste organic based upon historical sample analyses. The activity of Tc-99 was not in Reference 6, but was calculated based on its fission yield ratio to Cs-137 for coprocessing waste (Reference 4). Table 3 shows the source term for the major components of the organic waste.

Table 3. Major radionuclides and nitrate released at site CPP-15 in the organic portion of the waste.

	Cs-137	**Sr-90**	**H-3**	**Tc-99**	**I-129**	**NO_3**	**Pu**
CPP-15 Organic	7×10^{-6} microCi/mL	6×10^{-6} microCi/mL	Negligible*	1.1×10^{-9} microCi/mL	3×10^{-6} microCi/mL	Negligible*	1×10^{-3} microCi/mL

*Because the waste organic contained no water, the tritium activity and nitrate content were negligible.

The bulk of the CPP-15 contamination was removed shortly after the release and during the removal of the solvent burner and organic storage tank in the mid 1980s. This is shown by the low radionuclide activity (consistent with slightly contaminated backfill) in the 2004 soil samples from the near-surface locations. However, some of the 2004 soil samples from the deepest sites (10-12 feet below grade level) had elevated Cs-137 with low Pu activity. The elevated Cs-137 indicates not all contaminated soil was removed by previous cleanup efforts. Also, the relatively high Cs-137 and low Pu radionuclide activities are not consistent with the organic waste source term given above. Some of the contamination came from an aqueous waste. Condensate from the stack flowed into LE-102 forcing the waste organic to overflow. After the organic layer had overflowed, some of the stack condensate may have also overflowed. The stack condensate would have been relatively high in Cs-137 activity compared to the waste organic. The incident occurrence report indicates that the soil surface radiation after the spill was 3 R/hr. That radiation was too high to have been generated by the organic waste. By comparison, the waste organic storage tanks (NCE-184, -185, and -186) built to replace LE-102 were built above ground without any radiation shielding because the fission product content of the waste organic was so low. The 3R/hr soil radiation reading was about the same as surface contamination from condensate that seeped from the base of the stack (site CPP-29) later that year (November), which measured 1.5 R/hr (Reference 7). The similar soil surface radiation readings indicate that some of the CPP-15 contamination came from stack condensate (with relatively high Cs-137 activity) that overflowed LE-102.

A sample from the November 1974 stack seepage waste had a gross beta activity of 0.6 microCi/mL (Reference 7). Assuming equal activities of Cs-137, Sr-90 and Y-90, and the total activities of Ru-106/Rh-106 and Ce-144/Pr-144 equal to that of Cs-137, means the Cs-137 and Sr-90 activities were each about one fourth of the measured gross beta activity, or 0.15 microCi/mL. These fission product activities are four orders of magnitude higher than that in the organic portion of the waste. This means the aqueous condensate from the stack likely contributed the bulk of the fission product contamination to the soil. However, the organic portion was a significant contributor of the TRU components. The aqueous source term, based upon the November 1974 gross beta analysis is given in Table 4.

Table 4. Major radionuclides and nitrate released at site CPP-15 in the aqueous portion of the waste.

	Cs-137	**Sr-90**	**H-3**	**Tc-99**	**I-129**	**Pu**	**NO_3**
CPP-15 Aqueous	0.15 microCi/mL	0.15 microCi/mL	1.2 x 10-4 mciroCi/mL	2.4 x 10^{-5} microCi/mL	3.3 x 10^{-8} microCi/mL	1.8 x 10^{-3} microCi/mL	0.02 M

The aqueous source term uses fission yield values relative to Cs-137 from Reference 4 for Tc-99, I-129, H-3 and Pu. The Calciner was not in operation in March 1974. Thus the major radionuclides in the condensate likely came from residues inside the stack that were rinsed off by the condensate, not from adsorption of volatile material from the Calciner off-gas. The aqueous source term likely overestimates the H-3 and I-129 in the stack condensate because those isotopes likely did not form solid residues in the stack that would be in the stack condensate. Without the Calciner operation, the nitrate content of the condensate would have been low because the nitric acid-forming NO_x content of the stack gas would have been low. The nitrate in the condensate was likely 0.02 M or less.

Reference 5 indicates the waste flowed from the manway, across the concrete floor of the waste organic building, and out onto the soil, contaminating the near-surface soil. Some of the waste may have seeped between the tank manway and the building floor and down along the manway, causing the deeper areas of contamination found in the 2004 soil sampling.

Waste Volume Released

The incident occurrence report made no estimate of the volume of waste released to the site. It states that the solvent tank was initially partly full of organic waste. A reasonable assumption is that the tank was half full of organic waste, about 1000 liters, all of which overflowed onto the ground. The volume of condensate that formed and overflowed is also unknown. The condensate volume was limited by practical concerns. The spill area was next to a road/walkway that was used by people walking between the Waste Calcining Facility and other areas of the plant. A large spill that extended over a large area would likely have been noticed by passersby. There were no major flows of moist air into the stack that would form large volumes of condensate. The Calciner off-gas was the largest source of moist gas into the stack, but it was not in operation when the spill occurred. Other sources of moisture included the steam jets used to maintain a vacuum on the Zr fuel dissolver and vessel off-gas systems. The jets may have produced some steam condensate, but it was likely a small amount. A condensation rate of 5 gallons per hour is a reasonable estimate for the amount of condensate produced. During fuel dissolution and uranium extraction operations, waste organic is produced and must be burned. As a result operators or maintenance personnel would have entered the solvent burner building periodically to operate the facility or perform maintenance. In fact, the spill was discovered by maintenance personnel who entered the building to perform maintenance. Given these facts, it is unlikely the overflow situation existed for more than a few days.

A 5-gallon-per-hour leak would produce 120 gallons (about 500 liters) of condensate a day. It would take about 2 days for a tank that was half full of organic to fill with an organic/condensate mixture, another 2 days to force the organic (1000 liters) out of the tank and fill the tank with condensate, and another 2 days for 1000 liters of condensate to overflow onto the ground. This is a 6-day event, including 4 days of liquid leaking out of the flange. It is likely someone would have noticed the leak in that amount of time or less. Therefore a volume of 1000 liters each of organic and stack condensate is assumed to have leaked at the site. There is considerable uncertainty in this estimate, likely a factor of 2, but the release was likely hundreds of gallons not thousands of gallons.

CPP-15 Summary

CPP-15 was contaminated by waste organic (kerosene) produced by the first-cycle uranium extraction process, and by condensate from the main INTEC stack. The contamination occurred when construction activities cut the stack drain line, and closed a valve on a temporary drain system. Condensate formed in the stack, went down the stack drain line, and flowed into the waste organic storage tank, LE-102, via a water removal line that joined the stack drain line. The flow of stack condensate into LE-102 caused the organic waste to rise until it overflowed the tank via a ground-level flange on a tank manway. Condensate flowed from the stack into LE-102 until all the organic waste was forced out of the tank and then condensate overflowed the tank. This report assumes approximately 1000 liters each of organic waste and condensate flowed out of the tank and onto the surface of the soil. Some of the waste likely seeped down along the tank manway and contaminated a deep area of soil (12 feet below grade) in addition to the surface contamination.

A release of 1000 liters each of the organic waste and stack condensate spilled from the LE-102 tank with the source terms given in tables 3 and 4 results in estimated releases of the material shown in Table 5. The release estimates in Table 5 have a high degree of uncertainty, likely a factor of 2, due primarily to the uncertainty in the volume of waste released. However, less than 1 Ci of Cs-137 was released at site CPP-15. Compared to other releases in the Tank Farm area (such as CPP-31 where approximately 17,000 Ci of Cs was released) site CPP-15 contains insignificant quantities of fission products and should not affect groundwater models.

Table 5. Major radionuclides and nitrate released at CPP-15 in 1000 liters each of organic and stack condensate wastes.

	Cs-137	**Sr-90**	**H-3**	**Tc-99**	**I-129**	**NO_3**
Organic	7×10^{-6} Ci	6×10^{-6} Ci	0	1.1×10^{-6} mCi	3 microCi	0
Stack Condensate	0.15 Ci	0.15 Ci	0.12 mCi	0.024 mCi	0.033 microCi	1.2 kg
Total Released	0.15 Ci	0.15 Ci	0.12 mCi	0.024 mCi	3 microCi	1.2 kg

References

1. U. S. Department of Energy, *Operable Unit 3-14 Tank Farm Soil and Groundwater Remedial Investigation/Feasibility Study Work Plan*, DOE/ID-10676, Revision 1, June 2004.
2. M. C. Swenson, “Causes, Compositions, and Volumes of Waste Released at the INTEC Tank Farm in contamination Sites CPP-28, -31, -58E, and -79”, Internal Office Memorandum MCS-07-04, December 1, 2004.
3. Allied Chemical, “ICPP Tank Farm Contaminated Soil Incident October 1, 1974,” March 1, 1975.
4. D. R. Wenzel, “Assessment of Radioactivity in INTEC Soil Contamination Site 28”, EDF-5318, November 2004.
5. Allied Chemical Corporation, “Overflow of Solvent Burner Feed Tank”, Significant Operating Occurrence Report 74-10, April 1974.
6. R. C. Girton, *Final Safety Analysis Report for Fuel Processing Facilities Upgrade: Organic solvent Disposal system (Task 2)*, ENI-241, November 1983.
7. Allied Chemical Corporation, “Seepage of Contaminated Solution from CPP Main Stack”, Significant Operating Occurrence Report 74-31, November 1974.

Appendix A

Calculations of Waste Volume and Source Term for Waste Released at CPP-79 Deep

I. Waste Volume Released Calculations

1. Perform Steam Jet Dilution Calculations for 1966 Zr Waste Transfers (No Leaks)

February 1966 (volume data from Operations Monthly report): Zr waste transferred from both CPP-601 and CPP-604 to WM-188 and WM-189.

Waste received in WM-188/189:

WM-188/189 volume increase	88,600 gallons	
Waste from CPP-601	-43,100 gallons	
Waste from CPP-604 (difference)	45,500 gallons	

Waste sent from CPP-604 to WM-188/190:

WM-100	17,800 gallons	
WM-101	17,800 gallons	
WM-102	5,200 gallons	
WM-100 jet dilution*	+ 530 gallons	
Total CPP-604 Waste (Sum)		41,330 gallons

*WM-100 was transferred to WM-102 (assume 3% jet dilution) and then to WM-188/189

Jet dilution Calculation: Jet Dilution Volume = 45,500 – 41,330 = 4,170 gallons
Jet Dilution = 4,170/41,330 = 10%

These calculations show 10% jet dilution was an average value for wastes transferred from the CPP-604 tanks to the Tank Farm that did not leak to the soil.

2. Calculate Leakage for Three Transfers Through Valve Boxes A3A and A3B.

A. November 1967 WM-100/102 transfer

Transferred Al waste from WM-100 to WM-102 and then from WM-102 to WM-182 via box A3A (Data from Operation Monthly Reports):

Waste received in WM-182 (from WM-102) 6,795 gallons

Waste sent from CPP-604 to WM-182

Waste transferred from WM-100	6,100 gallons
WM-100 to WM-102 jet dilution (3%)	+ 183 gallons
Total liquid transferred	6,283 gallons

Jet Dilution Calculation: Jet Dilution Volume = 6,795 – 6,283 = 512 gallons
Jet Dilution = 512/6,283 = 8.1%

If jet dilution was 10% (628 gallons) the potential leak was: 628 – 512 = <u>116 gallons</u>

Assuming the drain line in valve box A3A was plugged, 116 gallons may have leaked into the tile encasements and then into the soil.

B. May 1973 WM-101 Transfer

Transferred Al waste from WM-101 to WM-183 via valve box A3B (Data from Operation Monthly reports):

Waste received in WM-183 from CPP-604	
Total WM-183 volume increase	6,300 gallons
First Cycle Raffinate from CPP-601 to WM-183	-768 gallons
Second Cycle Raffinate from CPP-601 to WM-183	-1,775 gallons
Net waste to WM-183 from CPP-604	3,757 gallons
Waste sent to WM-183 from CPP-604 (WM-101)	3,800 gallons

Jet Dilution Calculation: Jet Dilution Volume = 3,800 – 3,757 = -43 gallons
Jet Dilution = -43/3,800 = -1.1%

If the jet dilution was 10% (380 gallons) then the potential leak was: 380 – (-43) = 423 gallons.

Valve box A3B had a clear drain line in 1974. Thus most leaking waste went down the valve box drain line into the PEW Evaporator feed tank, WL-102, not into the tile line encasements. However, some waste may have leaked directly into the annular opening around the transfer lines in the floor. This would be a small portion of the waste (assume 10%), given the configuration of the valve box and piping.

Assume 10% of the total potential leak entered the tile encasements, about 42 gallons.

C. May 1973 WM-102 Transfer

Transferred first-cycle stainless steel waste from WM-102 to WM-189 (Data from Operation Monthly unless noted otherwise):

Waste received in WM-189 (from CPP-604)	5,440* gallons
Waste sent to WM-189 (from WM-102 in CPP-604)	5,150 gallons

* Monthly report had inadequate detail to determine volume changes for a given transfer in and out of WM-189 due to multiple transfers in and out of the tank during the month (the WCF calcined waste from the tank). Used the following information from shift supervisor log (May 16, 1973 graveyard shift) for the WM-189 volume calculation associated with the WM-102 transfer:

Shift Supervisor log: Level Recorder on WM-189 went from 51.2 to 72.0% (20.8% change)

Data for WM-189: 25 inch pressure range on level transducer (process knowledge)
SpG of waste = 1.17 (sample logs 73-3369 and 73-3376)
1224 gallons waste per inch of height in 50 ft diameter tank

WM-189 Volume Change = (0.208 x 25 inches pressure) x (1 inch height/1.17 inches pressure) x 1224 gallons/inch height
= 5440 gallons waste received in WM-189

Jet Dilution Calculation: Jet Dilution Volume = 5,440 – 5,150 = 290 gallons
Jet Dilution = 290/5,150 = 5.6%

If the jet dilution was 10% (515 gallons) the potential leak was: 515 – 290 = 225 gallons

Note the estimate for the WM-102 leak in 1973 (225 gallons) is larger than the leak estimate for 1967 (116 gallons), which is reasonable considering the ongoing deterioration of the valve gaskets over time.

D. Total Volume Leaked to CPP-79 Deep

Total volume leaked (estimated from three leaks in parts A through C)

WM-102 (1967)	116 gallons
WM-101 (1973)	42 gallons
WM-102 (1973)	225 gallons
Total potential leakage	383 gallons

Given the level of accuracy of the estimates, three significant digits are not warranted, so assume 400 gallons of waste leaked to CPP-79 deep.

II. CPP-79 Source Term Development

1. Background Data:

D. R. Wenzel[5] developed a CPP-79 composite source term based upon the Pu ratios in the 56-60 foot soil sample. The following is summary data (formal documentation to be issued in the future):

Composite source term = 0.98585 EBR + 0.1415 coprocessing
Coprocessing = 2.03 Al + Zr

fuel	g U-235 BOL	g U-235 EOL	1973 Ci Cs-137	2005 Ci Cs-137
Al	1073	550	1151	549.5
Zr	1000	400	1222	597.3
EBR	2950	2880	135.1	64.51

The above data are for arbitrary fuel "units".

Historically: Cs-137 activity = 1.0 Ci/L in Al, Zr and Coprocessing wastes
Cs-137 activity = 0.419 Ci/L in EBR (stainless steel) waste[6]

[5] D. R. Wenzel internet memo to M. C. Swenson dated February 9, 2005 titled "CPP-79 Source Term"

[6] W. J. Bjorklund, *First Electrolytic Dissolution Campaign of EBR-II Fuel at ICPP*, ICP-1028, February 1974, Table B-IV

2. Calculate Volume of Waste produced per Unit of Fuel

For Stainless steel: Activity = (135 Ci Cs-137/fuel unit) / (0.419 Ci Cs-137/L waste)
= 322 L waste / fuel unit

For Al fuel: Activity = (1151 Ci Cs-137/fuel unit) / (1.0 Ci Cs-137/L waste)
= 1151 L waste / fuel unit

For Zr fuel: Activity = (1222 Ci Cs-137/fuel unit) / (1.0 Ci Cs-137/L waste)
= 1222 L waste / fuel unit

Co processing waste (use Al and Zr data from above):

Waste = 2.03 x Al + Zr
= (2.03 x (1151) + 1222) / 3.03
= 1174 L waste / fuel unit

3. Calculate Relative Amount of Waste Types in CPP-79 Source Term (data from #1 and 2 above):

CPP-79 deep = 0.98585 x (EBR) + 0.1415 x (Co)
= 0.98585 x (322 L/fuel unit) + 0.1415 x (1174 L/fuel unit)
= 317 + 166
= 483 L waste

The stainless steel portion of CPP-79 deep source term = 317 / 483 = 0.656 = 66%
The coprocessing portion of CPP-79 deep source term = 1 - 66% = 34%

4. Calculate Cs-137 activity in composite CPP-79 deep source term*:

Cs-137 = (317 L x (0.419 Ci/L) + 166 L x (1.0 Ci/L)) / 483 L
Cs-137 = 0.619 Ci/L

*Note the D. R. Wenzel transmittal provided a complete radionuclide source term normalized to Cs-137 from which other radionuclides can be calculated.

5. For the 34-36 foot soil D. R. Wenzel developed a source term of:

Waste = 0.146 x Al + 0.853 x EBR

Calculate waste volumes from that Source term:

Waste = 0.146 x Al + 0.853 x EBR
= 0.146 x (1151) + 0.853 x 322
= 169.2 + 274.7
Waste = 443.9 L waste / fuel unit

EBR = 274.7/ 443.9 = 61.9% of the waste volume Al = 38.1% of waste volume

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Radiological Consequence Analysis Idaho Falls, Idaho 83402

March 22, 2005

L. S. Cahn
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Idaho Falls, ID 83415-3419

Subject: Assessment of radioactivity for INTEC site CPP-79 deep

Dear Lorie:

An assessment has been made of the radionuclide inventory for activity in INTEC site CPP-79 deep. The activity in two different depths has been evaluated, the 34-36 ft depth and the 56-60 ft depth. The modeling for the assessment of the activity follows.

The assessment began with the soil sample analysis results for the 56-60 ft depth. The analytical results used are presented in Table 1.

Table 1: Soil sample analysis results for CPP-79-deep at 56-60 ft depth (pCi/g)

Nuclide	Sample	Sample Error	MDA
H-3	1.16E+01	3.52E+01	1.20E+02
C-14	3.17E+00	1.35E+00	4.52E+00
Co-60	-1.28E+01	7.88E+00	2.17E+01
Mg-54	-1.05E+01	2.50E+01	5.46E+01
Zn-65	5.31E+01	3.87E+01	9.11E+01
Sr-90	3.47E+04	4.21E+02	2.26E+02
Tc-99	1.30E+01	5.67E-01	4.01E+00
Sb-125	-2.83E+02	8.64E+02	2.04E+03
I-129	3.96E+00	4.13E+00	4.39E+00
Ru-106	-2.28E+03	1.77E+03	4.01E+03
Ag-110m	1.58E+01	4.91E+01	2.97E+03
Cs-134	1.64E+01	2.60E+01	6.16E+01
Cs-137	1.35E+06	6.27E+04	6.62E+02
Ce-144	1.54E+03	1.37E+03	3.45E+03
Eu-152	-1.53E+01	3.36E+01	7.32E+01
Eu-154	-1.06E-03	3.89E+01	1.21E+02
Eu-155	-1.52E+03	6.44E+02	1.68E+03
U-233/234	3.34E+02	4.12E+01	4.62E+01
U-235	3.76E+01	1.62E+01	4.62E+01
U-238	8.35E+00	1.18E+01	4.62E+01
Np-237	6.99E+01	1.50E+01	3.61E+01
Pu-238[a]	2.27E+04	4.44E+02	5.99E+01
Pu-239/240[a]	1.46E+04	5.97E+02	3.21E+01
Pu-241	6.13E+02	1.77E+01	1.29E+01
Am-241	7.73E+02	5.35E+01	2.97E+01

[a]The average of 2 samples

As shown in Table 1, many of the soil analytical data are not appropriate for characterizing waste released because of the different transport rates of the radionuclides through the soil. Therefore, only ratios of the activity of isotopes of the same element or elements known to behave the same in soil can be used to characterize the release. The one ratio that fits this category is the Pu-238:Pu-239/240 ratio. The Pu-238 and Pu-239/240 results were used to establish the types of fuels involved in the leak.

The ORIGEN2 code (Croff 1980) was used to calculate typical radionuclide inventories for the three different types of fuel. Copies of the ORIGEN2 runs are presented in Attachments 1-3 respectively for Al-clad, Zr-clad, and EBR-II fuels.

The typical ratio of Pu-238:Pu-239/240 for the three types of fuels are shown in Table 2.

Table 2: Ratio of Pu-238:Pu-239+240 for different fuels

Fuel Type	Pu-228:Pu-239+240 Ratio
Zr-clad	100
Al-clad	35
EBR-II (stainless steel-clad)	0.1

The measured ratio of 0.724 indicates that the majority of the waste had to have come from the reprocessing of EBR-II fuel.

An evaluation of waste transfers that could have resulted in the leak showed a single transfer in 1969 and two transfers in 1973 as the potential times of the leak (Swenson 2005). It was hoped that the Am-241:Pu-241 ratio could be used to confirm the leak date. However, the measured ratio of 1.26 indicated a fuel that would have had to be processed subsequent to the 1973 date. As this is not possible, it was concluded after inquiring about the reliability of the Pu-241 laboratory analysis technique, that the Pu-241 results are likely high.

As valves and gaskets tend to deteriorate more with age, it was concluded that the most likely time of the leak was in 1973. The indication that the waste represents more than one type of fuel also supports the 1973 time for the leak (Staiger 2003). Various mixes of the fuel types were evaluated. The fuel mix that best fits the analytical sample results is shown in the following equation:

$$CPP\text{-}79_{56-60} = 0.98585\,EBR + 0.01415\left[2.03\,Al + Zr\right]$$

where,

EBR = 39 year decayed EBR-II MARK-II fuel
Al = 38 year decayed Al-clad fuel
Zr = 38 year decayed Zr-clad fuel

Migration of the activity through the soil to the 56-60 ft depth has a major impact on the ratio of radionuclides observed in the sample. Plant knowledge has therefore been used to determine the relative amounts of U and fission products that would have been present at the point of release.

Wastes involved in the leak are believed to have come from a mix of 1st, 2nd and 3rd cycle wastes. The amount of U in wastes sent to the CPP-604 tanks was carefully monitored because of the value of the U and the concern for a potential criticality accident in one of the deep tanks. Historically, less than 0.01% of the U was released in the waste streams. The U was therefore reduced by a factor of 0.0001 to account for the reduction of U in the fuel, as calculated by ORIGEN2, to U in the waste leaked to the soil after the U has been extracted during reprocessing. As all of the radionuclides other than U are released to the 1st, 2nd, or 3rd cycle wastes, their relative activities were assumed to be proportional to that in the fuel mix indicated as described above.

Following the separation of the U from the other radionuclides, the daughter products of U in the waste were not in equilibrium with the remaining U present in the waste. It was therefore necessary to decay correct the radionuclide from the assumed 1973 reprocessing time to the current time. This required the ORIGEN2 runs in Attachments 1, 2, and 3 to be revised to give the mass of each of the radionuclides decay corrected to the year 1973. Copies of the revised ORIGEN2 runs are presented in Attachments 4, 5, and 6.

Next, the mass of each radionuclide in the mix of the 3 types of fuels involved in the leak were calculated using a Fortran program called MIX56_60. A copy of the source listing for program MIX56_60 is presented in Attachment 7. Program MIX56_60 uses as input the output files from the ORIGEN2 runs in Attachments 4, 5 and 6. Program MIX56_60 uses file MASTER as input. A copy of file MASTER is presented in Attachment 7. A copy of the output from program MIX56_60 is presented in Attachment 8.

The output from program MIX56_60 was reformatted as input to another ORIGEN2 run that is presented in Attachment 9. This ORIGEN2 run decay corrected the radionuclide activities from the year 1973 to 2005. Another Fortran program called SHORT79D was written to:

- reduce the output from ORIGEN2 run CPP79D to a shortened list of radionuclides
- add inventories of multiple entries of the same radionuclide
- normalize the results for each of the decay times to 1 Ci of Cs-137
- round the output to 2 places of accuracy
- add half-lives for better radionuclide identification.

A copy of the source listing and output for program SHORT79D are presented in Attachment 10. Program SHORT79D uses file MASTER.NUC as input. A copy of file MASTER.NUC is presented in Attachment 10. The calculated radionuclide inventory for the 56-60 ft depth at the point of release is presented in Table 3.

Table 3: Calculated radionuclide activities for the CPP-79-deep 56-60 foot depth normalized to Cs-137

Nuclide	Half-Life		1973 Normalized Activity	2005 Normalize d Activity
H-3	1.233E+01	yr	5.60E-03	1.90E-03
Be-10	1.510E+06	yr	1.20E-10	2.40E-10
C-14	5.730E+03	yr	1.20E-06	2.40E-06
Mn-54	3.123E+02	d	1.00E-02	1.20E-13
Fe-55	2.730E+00	yr	2.70E-02	1.10E-05
Co-60	5.271E+00	yr	5.80E-04	1.80E-05
Ni-59	7.600E+04	yr	2.30E-05	4.70E-05
Ni-63	1.001E+02	yr	2.90E-03	4.70E-03
Se-79	1.130E+06	yr	5.80E-06	1.20E-05
Rb-87	4.750E+10	yr	3.10E-10	6.60E-10
Sr-90	2.878E+01	yr	9.30E-01	9.10E-01
Zr-93	1.530E+06	yr	2.80E-05	5.90E-05
Nb-93m	1.613E+01	yr	8.60E-06	4.80E-05
Nb-94	2.030E+04	yr	6.80E-07	1.40E-06
Tc-98	4.200E+06	yr	1.90E-11	3.90E-11
Tc-99	2.111E+05	yr	1.60E-04	3.40E-04
Ru-106	3.736E+02	d	2.40E-02	1.40E-11
Ag-108	2.370E+00	m	2.10E-13	1.30E-13
Ag-108m	4.180E+02	yr	7.20E-13	1.40E-12
Cd-109	4.626E+02	d	1.50E-11	8.00E-19
Cd-113m	1.410E+01	yr	4.00E-04	1.70E-04
In-115	4.410E+14	yr	9.40E-16	2.00E-15
Sn-121m	5.500E+01	yr	9.30E-06	1.30E-05
Sn-126	1.000E+05	yr	1.10E-05	2.30E-05
Sb-125	2.758E+00	yr	4.50E-02	3.20E-05
Sb-126	1.246E+01	d	1.50E-06	3.20E-06
Sb-126m	1.915E+01	m	1.10E-05	2.30E-05
Te-123	1.000E+13	yr	4.20E-18	8.70E-18
Te-125m	5.740E+01	d	1.10E-02	7.70E-06
I-129	1.570E+07	yr	3.80E-07	8.00E-07
Cs-134	2.065E+00	yr	3.60E-02	1.60E-06
Cs-135	2.300E+06	yr	1.30E-05	2.70E-05
Cs-137	3.007E+01	yr	1.00E+00	1.00E+00
Ce-142	5.000E+16	yr	3.20E-10	6.60E-10
Ce-144	2.849E+02	d	6.80E-02	5.90E-14
Pr-144	1.728E+01	m	6.80E-02	5.90E-14

Table 3: Calculated radionuclide activities for the CPP-79-deep 56-60 foot depth normalized to Cs-137 (Continued)

Nuclide	Half-Life		1973 Normalized Activity	2005 Normalized Activity
Nd-144	2.290E+15	yr	1.50E-14	3.20E-14
Pm-146	5.530E+00	yr	7.70E-06	2.80E-07
Pm-147	2.623E+00	yr	6.70E-01	3.00E-04
Sm-146	1.030E+08	yr	7.30E-13	2.00E-12
Sm-147	1.060E+11	yr	9.80E-11	2.40E-10
Sm-148	7.000E+15	yr	1.00E-16	2.20E-16
Sm-149	2.000E+15	yr	4.80E-16	1.00E-15
Sm-151	9.000E+01	yr	2.10E-02	3.40E-02
Eu-150	3.690E+01	yr	3.90E-10	4.40E-10
Eu-152	1.354E+01	yr	1.90E-05	7.80E-06
Eu-154	8.593E+00	yr	8.60E-03	1.40E-03
Eu-155	4.761E+00	yr	2.20E-02	4.30E-04
Gd-152	1.080E+14	yr	2.60E-18	6.60E-18
Ho-166m	1.200E+03	yr	3.60E-10	7.40E-10
Tm-171	1.920E+00	yr	1.30E-12	2.60E-17
Tl-207	4.770E+00	m	6.60E-10	8.10E-09
Tl-208	3.053E+00	m	6.90E-08	5.00E-09
Tl-209	2.200E+00	m	1.40E-13	3.00E-13
Pb-209	3.253E+00	h	6.40E-12	1.40E-11
Pb-210	2.230E+01	yr	9.40E-12	9.10E-10
Pb-211	3.610E+01	m	6.60E-10	8.10E-09
Pb-212	1.064E+01	h	1.90E-07	1.40E-08
Pb-214	2.680E+01	m	1.20E-10	2.30E-09
Bi-208	3.680E+05	yr	1.10E-24	2.30E-24
Bi-210	5.013E+00	d	9.40E-12	9.10E-10
Bi-210m	3.040E+06	yr	4.10E-25	8.60E-25
Bi-211	2.140E+00	m	6.60E-10	8.10E-09
Bi-212	6.055E+01	m	1.90E-07	1.40E-08
Bi-213	4.559E+01	m	6.40E-12	1.40E-11
Bi-214	1.990E+01	m	1.20E-10	2.30E-09
Po-210	1.384E+02	d	9.40E-12	9.10E-10
Po-211	5.160E-01	s	1.90E-12	2.30E-11
Po-214	1.643E-04	s	1.20E-10	2.30E-09
Po-215	1.781E-03	s	6.60E-10	8.10E-09
Po-216	1.450E-01	s	1.90E-07	1.40E-08
Po-218	3.100E+00	m	1.20E-10	2.30E-09
At-217	3.230E-02	s	6.40E-12	1.40E-11
Fr-221	4.900E+00	m	6.40E-12	1.40E-11
Fr-223	2.180E+00	m	9.10E-12	1.10E-10
Ra-223	1.144E+01	d	6.60E-10	8.10E-09
Ra-224	3.660E+00	d	1.90E-07	1.40E-08
Ra-225	1.490E+01	d	6.40E-12	1.40E-11
Ra-226	1.600E+03	yr	1.20E-10	2.30E-09

Table 3: Calculated radionuclide activities for the CPP-79-deep 56-60 foot depth normalized to Cs-137 (Continued)

Nuclide	Half-Life		1973 Normalized Activity	2005 Normalized Activity
Ra-228	5.750E+00	yr	1.10E-15	6.20E-15
Ac-225	1.000E+01	d	6.40E-12	1.40E-11
Ac-227	2.177E+01	yr	6.60E-10	8.10E-09
Ac-228	6.150E+00	h	9.20E-16	6.20E-15
Th-227	1.872E+01	d	6.50E-10	8.00E-09
Th-228	1.912E+00	yr	1.90E-07	1.40E-08
Th-229	7.340E+03	yr	6.40E-12	1.40E-11
Th-230	7.538E+04	yr	7.00E-08	1.50E-07
Th-231	2.552E+01	h	3.40E-05	7.20E-09
Th-232	1.405E+10	yr	3.00E-15	6.30E-15
Th-234	2.410E+01	d	4.70E-06	9.90E-10
Pa-231	3.276E+04	yr	5.70E-09	1.20E-08
Pa-233	2.697E+01	d	1.30E-06	2.80E-06
Pa-234	6.700E+00	h	6.20E-09	1.30E-12
Pa-234m	1.170E+00	m	4.70E-06	9.90E-10
U-232	6.890E+01	yr	2.20E-11	1.30E-08
U-233	1.592E+05	yr	7.00E-13	3.90E-10
U-234	2.455E+05	yr	9.80E-08	6.20E-07
U-235	7.038E+08	yr	3.40E-09	7.20E-09
U-236	2.342E+07	yr	8.00E-10	1.70E-09
U-237	6.750E+00	d	1.10E-12	4.90E-09
U-238	4.470E+09	yr	4.70E-10	9.90E-10
Np-235	3.961E+02	d	2.90E-10	8.00E-19
Np-237	2.144E+06	yr	1.30E-06	2.80E-06
Np-238	2.117E+00	d	5.60E-11	1.10E-10
Np-239	2.356E+00	d	1.20E-08	2.40E-08
Np-240m	7.220E+00	m	5.30E-16	1.10E-15
Pu-236	2.858E+00	yr	2.00E-07	1.80E-10
Pu-238	8.770E+01	yr	2.50E-03	4.10E-03
Pu-239	2.411E+04	yr	2.60E-03	5.50E-03
Pu-240	6.563E+03	yr	2.40E-05	5.00E-05
Pu-241	1.435E+01	yr	4.50E-04	2.00E-04
Pu-242	3.733E+05	yr	2.90E-09	6.10E-09
Pu-244	8.080E+07	yr	5.40E-16	1.10E-15
Am-241	4.322E+02	yr	5.30E-06	3.40E-05
Am-242	1.602E+01	h	1.10E-08	2.20E-08
Am-242m	1.410E+02	yr	1.20E-08	2.20E-08
Am-243	7.370E+03	yr	1.20E-08	2.40E-08
Cm-242	1.628E+02	d	1.10E-08	1.80E-08

Table 3: Calculated radionuclide activities for the CPP-79-deep 56-60 foot depth normalized to Cs-137 (Continiued)

Nuclide	Half-Life	1973 Normalized Activity	2005 Normalized Activity
Cm-243	2.910E+01 yr	3.60E-09	3.50E-09
Cm-244	1.810E+01 yr	4.00E-07	2.50E-07
Cm-245	8.500E+03 yr	2.10E-11	4.40E-11
Cm-246	4.730E+03 yr	1.80E-12	3.80E-12
Cm-247	1.560E+07 yr	2.30E-18	4.90E-18
Cm-248	3.400E+05 yr	2.50E-18	5.30E-18
Cf-249	3.510E+02 yr	1.50E-17	2.90E-17
Cf-250	1.308E+01 yr	3.90E-17	1.50E-17
Cf-251	8.980E+02 yr	2.30E-19	4.60E-19

Again, most of the soil analytical data were not used for characterizing the waste released because of the differential transport rates of the radionuclides through the soil. However, the ratio of Pu-238:Pu-239/240 was used to establish the relative amounts of the different types of fuels involved in the leak. Similarly to the 56-60 ft depth, the measured ratio of Pu-238:Pu-239/240 of 1.71 indicates that a significant portion of the leak came from EBR-II fuel reprocessing. Because no Zr was observed in the sample from this elevation, it was assumed that the leak was a mixture of Al-clad fuel and EBR-II fuel. The fuel mix that best fits the analytical sample results is shown in the following equation:

$$CPP{-}79_{34-36} = 0.85300\,EBR + 0.0.147\,Al$$

where,

EBR = 39 year decayed EBR-II MARK-II fuel
Al = 38 year decayed Al-clad fuel

As discussed above, a release fraction of 0.0001 was again used for the U. As in the 56-60 ft case, a Fortran program called MIX34_36 was written to calculate the mass of the mix of the 2 types of fuel assumed to be involved with the leak. A copy of the source listing for program MIX34_36 is presented in Attachment 11. Program MIX34_36 uses as input the output files from ORIGEN2 runs in Attachments 4 and 5. A copy of the output from program MIX34_36 is presented in Attachment 11.

The output from program MIX34_36 was reformatted as input to another ORIGEN2 run that is presented in Attachment 12. This ORIGEN2 run decay corrects the radionuclide activities from the year 1973 to 2005. Another Fortran program called SHORT79M was written which is very similar to program SHORT79D described above. A copy of the source listing and the output for program SHORT79M is presented in Attachment 13. The calculated radionuclide inventory for the 34-36 ft depth at the point of release is presented in Table 5.

Table 5: Calculated radionuclide activities for the CPP-79-deep 34-36 foot depth normalized to Cs-137

Nuclide	Half-Life		1973 Normalized Activity	2005 Normalized Activity
H-3	1.233E+01	yr	4.70E-03	1.60E-03
Be-10	1.510E+06	yr	7.90E-11	1.70E-10
C-14	5.730E+03	yr	1.40E-09	2.80E-09
Mn-54	3.123E+02	d	5.70E-03	6.50E-14
Fe-55	2.730E+00	yr	1.50E-02	6.20E-06
Co-60	5.271E+00	yr	3.20E-04	9.90E-06
Ni-59	7.600E+04	yr	1.20E-05	2.60E-05
Ni-63	1.001E+02	yr	1.50E-03	2.50E-03
Se-79	1.130E+06	yr	5.30E-06	1.10E-05
Rb-87	4.750E+10	yr	3.10E-10	6.50E-10
Sr-90	2.878E+01	yr	9.40E-01	9.20E-01
Zr-93	1.530E+06	yr	2.40E-05	5.00E-05
Nb-93m	1.613E+01	yr	6.60E-06	4.10E-05
Nb-94	2.030E+04	yr	5.40E-08	1.10E-07
Tc-98	4.200E+06	yr	2.30E-11	4.80E-11
Tc-99	2.111E+05	yr	1.60E-04	3.30E-04
Ru-106	3.736E+02	d	2.90E-02	1.70E-11
Ag-108	2.370E+00	m	1.30E-13	8.10E-14
Ag-108m	4.180E+02	yr	4.60E-13	9.10E-13
Cd-109	4.626E+02	d	1.60E-11	9.00E-19
Cd-113m	1.410E+01	yr	2.80E-04	1.20E-04
In-115	4.410E+14	yr	5.70E-16	1.20E-15
Sn-121m	5.500E+01	yr	2.30E-06	3.10E-06
Sn-126	1.000E+05	yr	8.00E-06	1.70E-05
Sb-125	2.758E+00	yr	3.20E-02	2.20E-05
Sb-126	1.246E+01	d	1.10E-06	2.30E-06
Sb-126m	1.915E+01	m	7.90E-06	1.70E-05
Te-123	1.000E+13	yr	1.70E-18	3.70E-18
Te-125m	5.740E+01	d	7.70E-03	5.40E-06
I-129	1.570E+07	yr	3.20E-07	6.80E-07
Cs-134	2.065E+00	yr	7.70E-02	3.50E-06
Cs-135	2.300E+06	yr	7.20E-06	1.50E-05
Cs-137	3.007E+01	yr	1.00E+00	1.00E+00
Ce-142	5.000E+16	yr	3.20E-10	6.60E-10
Ce-144	2.849E+02	d	1.10E-01	1.00E-13
Pr-144	1.728E+01	m	1.10E-01	1.00E-13
Nd-144	2.290E+15	yr	1.60E-14	3.30E-14
Pm-146	5.530E+00	yr	9.40E-06	3.50E-07
Pm-147	2.623E+00	yr	6.70E-01	3.00E-04
Sm-146	1.030E+08	yr	5.10E-13	1.60E-12
Sm-147	1.060E+11	yr	8.30E-11	2.10E-10
Sm-148	7.000E+15	yr	1.20E-16	2.60E-16

Table 5: Calculated radionuclide activities for the CPP-79-deep 34-36 foot depth normalized to Cs-137 (Continued)

Nuclide	Half-Life	1973 Normalized Activity	2005 Normalized Activity
Sm-149	2.000E+15 yr	2.80E-16	5.90E-16
Sm-151	9.000E+01 yr	1.40E-02	2.20E-02
Eu-150	3.690E+01 yr	2.20E-10	2.50E-10
Eu-152	1.354E+01 yr	1.50E-05	6.00E-06
Eu-154	8.593E+00 yr	1.70E-02	2.60E-03
Eu-155	4.761E+00 yr	1.70E-02	3.40E-04
Gd-152	1.080E+14 yr	1.00E-18	3.00E-18
Ho-166m	1.200E+03 yr	3.90E-10	8.00E-10
Tm-171	1.920E+00 yr	3.00E-12	6.10E-17
Tl-207	4.770E+00 m	3.70E-10	4.60E-09
Tl-208	3.053E+00 m	4.40E-08	7.80E-09
Tl-209	2.200E+00 m	7.70E-14	1.80E-13
Pb-209	3.253E+00 h	3.60E-12	8.20E-12
Pb-210	2.230E+01 yr	5.20E-12	5.10E-10
Pb-211	3.610E+01 m	3.80E-10	4.60E-09
Pb-212	1.064E+01 h	1.20E-07	2.20E-08
Pb-214	2.680E+01 m	6.80E-11	1.30E-09
Bi-208	3.680E+05 yr	3.50E-25	7.40E-25
Bi-210	5.013E+00 d	5.20E-12	5.10E-10
Bi-210m	3.040E+06 yr	1.40E-26	3.00E-26
Bi-211	2.140E+00 m	3.80E-10	4.60E-09
Bi-212	6.055E+01 m	1.20E-07	2.20E-08
Bi-213	4.559E+01 m	3.60E-12	8.20E-12
Bi-214	1.990E+01 m	6.80E-11	1.30E-09
Po-210	1.384E+02 d	5.20E-12	5.10E-10
Po-211	5.160E-01 s	1.10E-12	1.30E-11
Po-214	1.643E-04 s	6.80E-11	1.30E-09
Po-215	1.781E-03 s	3.80E-10	4.60E-09
Po-216	1.450E-01 s	1.20E-07	2.20E-08
Po-218	3.100E+00 m	6.80E-11	1.30E-09
At-217	3.230E-02 s	3.60E-12	8.20E-12
Fr-221	4.900E+00 m	3.60E-12	8.20E-12
Fr-223	2.180E+00 m	5.20E-12	6.40E-11
Ra-223	1.144E+01 d	3.80E-10	4.60E-09
Ra-224	3.660E+00 d	1.20E-07	2.20E-08
Ra-225	1.490E+01 d	3.60E-12	8.20E-12
Ra-226	1.600E+03 yr	6.80E-11	1.30E-09
Ra-228	5.750E+00 yr	7.90E-16	4.80E-15
Ac-225	1.000E+01 d	3.60E-12	8.20E-12
Ac-227	2.177E+01 yr	3.70E-10	4.60E-09
Ac-228	6.150E+00 h	6.80E-16	4.80E-15
Th-227	1.872E+01 d	3.70E-10	4.50E-09
Th-228	1.912E+00 yr	1.20E-07	2.20E-08

Table 5: Calculated radionuclide activities for the CPP-79-deep 34-36 foot depth normalized to Cs-137

Nuclide	Half-Life		1973 Normalized Activity	2005 Normalized Activity
Th-229	7.340E+03	yr	3.60E-12	8.20E-12
Th-230	7.538E+04	yr	3.90E-08	8.20E-08
Th-231	2.552E+01	h	1.90E-05	4.10E-09
Th-232	1.405E+10	yr	2.30E-15	4.90E-15
Th-234	2.410E+01	d	2.70E-06	5.60E-10
Pa-231	3.276E+04	yr	3.20E-09	6.80E-09
Pa-233	2.697E+01	d	1.80E-06	3.80E-06
Pa-234	6.700E+00	h	3.50E-09	7.20E-13
Pa-234m	1.170E+00	m	2.70E-06	5.60E-10
U-232	6.890E+01	yr	1.50E-11	2.10E-08
U-233	1.592E+05	yr	4.00E-13	5.20E-10
U-234	2.455E+05	yr	5.50E-08	6.70E-07
U-235	7.038E+08	yr	1.90E-09	4.10E-09
U-236	2.342E+07	yr	6.80E-10	1.50E-09
U-237	6.750E+00	d	3.20E-12	1.40E-08
U-238	4.470E+09	yr	2.70E-10	5.60E-10
Np-235	3.961E+02	d	4.70E-10	1.30E-18
Np-237	2.144E+06	yr	1.80E-06	3.80E-06
Np-238	2.117E+00	d	6.30E-11	1.20E-10
Np-239	2.356E+00	d	3.20E-08	6.70E-08
Np-240m	7.220E+00	m	1.70E-15	3.60E-15
Pu-236	2.858E+00	yr	3.20E-07	2.90E-10
Pu-238	8.770E+01	yr	3.30E-03	5.40E-03
Pu-239	2.411E+04	yr	1.50E-03	3.10E-03
Pu-240	6.563E+03	yr	2.30E-05	4.80E-05
Pu-241	1.435E+01	yr	1.30E-03	5.80E-04
Pu-242	3.733E+05	yr	8.40E-09	1.80E-08
Pu-244	8.080E+07	yr	1.70E-15	3.60E-15
Am-241	4.322E+02	yr	1.50E-05	9.70E-05
Am-242	1.602E+01	h	1.30E-08	2.40E-08
Am-242m	1.410E+02	yr	1.40E-08	2.40E-08
Am-243	7.370E+03	yr	3.20E-08	6.70E-08
Cm-242	1.628E+02	d	1.50E-08	2.00E-08
Cm-243	2.910E+01	yr	5.70E-09	5.40E-09
Cm-244	1.810E+01	yr	1.10E-06	6.60E-07
Cm-245	8.500E+03	yr	5.40E-11	1.10E-10
Cm-246	4.730E+03	yr	4.30E-12	9.10E-12
Cm-247	1.560E+07	yr	5.00E-18	1.00E-17
Cm-248	3.400E+05	yr	4.50E-18	9.50E-18
Cf-249	3.510E+02	yr	2.40E-17	4.70E-17
Cf-250	1.308E+01	yr	6.30E-17	2.40E-17
Cf-251	8.980E+02	yr	3.10E-19	6.40E-19

1560 Mountain Rose
Idaho Falls, Idaho 83402

References

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Staiger, M. D., 2003, *Calcined Waste Storage at the Idaho Nuclear Technology and Engineering Center*, INEEL/EXT-98-00455, Rev. 1, June 2003.

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D. R. Wenzel

Attachments

DR WENZEL CONSULTING INC
Radiological Consequence Analysis

1560 Mountain Rose
Idaho Falls, Idaho 83402

L. S. Cahn
March 22, 2005
Attachment 1
1 of 5

ORIGEN2 run ATR Input

```
-1
-1
-1
  RDA     ORIGEN2, VERSION 2.1 (8-1-91) ATR
  TIT     THREE CYCLES WITN 48.74% BURNUP
  BAS     ONE ATR ELEMENT
  CUT     -1
  LIP     0 0 0
  LIB     0  1 2 3  0  205  206   9   0   0  1  1
  PHO     101  102  103  10
  INP     -1   1  -1  -1  1  1
  MOV     -1   1   0   1.0
  HED      1                                                        ELEMENT
  BUP
  IRP      2.5   10.0   1   2   4 2
  IRP      5.0   10.0   2   3   4 0
  IRP      7.5   10.0   3   4   4 0
  IRP     10.0   10.0   4   5   4 0
  IRP     12.5   10.0   5   6   4 0
  IRP     15.0   10.0   6   7   4 0
  DEC     30.0          7   8   4 0
  OUT      8    1    0    0
  IRP     35.0    6.5   8   1   4 0
  IRP     40.0    6.5   1   2   4 0
  IRP     45.0    6.5   2   3   4 0
  IRP     50.0    6.5   3   4   4 0
  IRP     55.0    6.5   4   5   4 0
  IRP     60.0    6.5   5   6   4 0
  DEC     90.0          6   7   4 0
  OUT      7    1    0    0
  IRP     95.0   2.176   7   1   4 0
  IRP    100.0   2.176   1   2   4 0
  IRP    105.0   2.176   2   3   4 0
  IRP    110.0   2.176   3   4   4 0
  IRP    115.0   2.176   4   5   4 0
  IRP    120.0   2.176   5   6   4 0
  BUP
  OPTL    8 8 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTA    8 8 8 8 5   8 5 8 5 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTF    8 8 8 8 8   8 5 8 5 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  MOV      6    1    0   1.0
  DEC      38.     1   2   5   4
  DEC      39.     2   3   5   0
  DEC      40.     3   4   5   0
  DEC      41.     4   5   5   0
  DEC      42.     5   6   5   0
  DEC      43.     6   7   5   0
  OUT      -7      1     -1    0
  OUT       7      1     -1    0
```

ORIGEN2 run ATR Input (Continued)

```
  END
  2   922350  1073. 922360  3.368  922380  74.62  0    0.0   FUEL 93.2%
  0
```

ORIGEN2 run ATR BAT File

```
echo off
echo **                                                              **
echo **                  O R I G E N 2                               **
echo **                                                              **
copy atr.INP tape5.inp >nul
REM  (NOT USED IN THIS CASE) copy atr.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\pwru.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
echo finished with origen2 calculation
rem  combine and save files from run
copy tape12.out+tape6.out atr.u6 >nul
copy tape13.out+tape11.out atr.u11 >nul
ren tape7.out atr.pch
ren tape15.out atr.dbg
ren tape16.out atr.vxs
ren tape50.out atr.ech
rem  cleanup files
del tape*.inp
del tape*.out
echo ************************************************************************
echo ******************* O R I G E N 2 - Version 2.1 **********************
echo *********************** Execution Completed *************************
echo ************************************************************************
echo on
```

ORIGEN2 run ATR Summarized Output

	120.0D	38.0YR	39.0YR	40.0YR	41.0YR	42.0YR	43.0YR
TL206	9.455E-25	9.455E-25	9.455E-25	9.455E-25	9.455E-25	9.455E-25	9.455E-25
TL207	2.278E-11	4.060E-07	4.247E-07	4.428E-07	4.611E-07	4.796E-07	4.983E-07
TL208	3.960E-08	2.641E-05	2.625E-05	2.600E-05	2.575E-05	2.551E-05	2.526E-05
TL209	4.150E-13	2.424E-11	2.539E-11	2.657E-11	2.777E-11	2.901E-11	3.027E-11
PB209	1.923E-11	1.122E-09	1.175E-09	1.230E-09	1.286E-09	1.343E-09	1.401E-09
PB210	1.350E-13	2.658E-10	2.896E-10	3.148E-10	3.414E-10	3.696E-10	3.994E-10
PB211	2.284E-11	4.072E-07	4.259E-07	4.440E-07	4.624E-07	4.809E-07	4.997E-07
PB212	1.102E-07	7.350E-05	7.306E-05	7.237E-05	7.167E-05	7.099E-05	7.031E-05
PB214	1.276E-14	1.008E-09	1.077E-09	1.150E-09	1.225E-09	1.304E-09	1.385E-09
BI208	1.283E-24	1.283E-24	1.283E-24	1.283E-24	1.283E-24	1.283E-24	1.283E-24
BI210M	9.493E-25	9.493E-25	9.493E-25	9.493E-25	9.493E-25	9.493E-25	9.493E-25
BI210	1.095E-13	2.658E-10	2.897E-10	3.149E-10	3.416E-10	3.699E-10	3.997E-10
BI211	2.284E-11	4.072E-07	4.259E-07	4.440E-07	4.624E-07	4.809E-07	4.997E-07
BI212	1.102E-07	7.350E-05	7.306E-05	7.237E-05	7.167E-05	7.099E-05	7.031E-05
BI213	1.921E-11	1.122E-09	1.175E-09	1.230E-09	1.286E-09	1.343E-09	1.401E-09
BI214	1.276E-14	1.008E-09	1.077E-09	1.150E-09	1.225E-09	1.304E-09	1.385E-09
PO210	1.485E-14	2.658E-10	2.757E-10	2.978E-10	3.230E-10	3.500E-10	3.786E-10
PO211	6.395E-14	1.140E-09	1.193E-09	1.243E-09	1.295E-09	1.347E-09	1.399E-09
PO212	7.061E-08	4.709E-05	4.681E-05	4.636E-05	4.592E-05	4.548E-05	4.505E-05
PO213	1.880E-11	1.098E-09	1.150E-09	1.203E-09	1.258E-09	1.314E-09	1.371E-09
PO214	5.351E-11	1.008E-09	1.077E-09	1.149E-09	1.225E-09	1.303E-09	1.385E-09
PO215	2.283E-11	4.072E-07	4.259E-07	4.440E-07	4.624E-07	4.809E-07	4.997E-07
PO216	1.102E-07	7.350E-05	7.306E-05	7.237E-05	7.167E-05	7.099E-05	7.031E-05
PO218	1.276E-14	1.008E-09	1.077E-09	1.150E-09	1.225E-09	1.304E-09	1.386E-09
AT217	1.921E-11	1.122E-09	1.175E-09	1.230E-09	1.286E-09	1.343E-09	1.401E-09
RN219	2.283E-11	4.072E-07	4.259E-07	4.440E-07	4.624E-07	4.809E-07	4.997E-07
RN220	1.102E-07	7.350E-05	7.306E-05	7.237E-05	7.167E-05	7.099E-05	7.031E-05
RN222	1.276E-14	1.008E-09	1.077E-09	1.150E-09	1.225E-09	1.304E-09	1.386E-09
FR221	1.921E-11	1.122E-09	1.175E-09	1.230E-09	1.286E-09	1.343E-09	1.401E-09
FR223	6.053E-13	5.619E-09	5.865E-09	6.115E-09	6.367E-09	6.623E-09	6.881E-09
RA223	2.283E-11	4.072E-07	4.259E-07	4.440E-07	4.624E-07	4.809E-07	4.997E-07
RA224	1.102E-07	7.350E-05	7.306E-05	7.237E-05	7.167E-05	7.099E-05	7.031E-05
RA225	3.271E-11	1.122E-09	1.175E-09	1.230E-09	1.286E-09	1.343E-09	1.401E-09
RA226	1.428E-14	1.008E-09	1.077E-09	1.150E-09	1.225E-09	1.304E-09	1.386E-09
RA228	8.895E-16	8.665E-12	8.961E-12	9.258E-12	9.555E-12	9.852E-12	1.015E-11
AC225	1.921E-11	1.122E-09	1.175E-09	1.230E-09	1.286E-09	1.343E-09	1.401E-09
AC227	4.386E-11	4.072E-07	4.250E-07	4.431E-07	4.614E-07	4.799E-07	4.986E-07
AC228	2.050E-09	8.665E-12	8.962E-12	9.258E-12	9.555E-12	9.853E-12	1.015E-11
TH227	2.995E-11	4.015E-07	4.201E-07	4.379E-07	4.560E-07	4.743E-07	4.928E-07
TH228	1.247E-07	7.350E-05	7.280E-05	7.210E-05	7.141E-05	7.073E-05	7.005E-05
TH229	3.494E-12	1.122E-09	1.175E-09	1.230E-09	1.286E-09	1.343E-09	1.401E-09
TH230	2.533E-10	1.580E-07	1.649E-07	1.719E-07	1.790E-07	1.862E-07	1.936E-07
TH231	1.219E-03	1.189E-03	1.189E-03	1.189E-03	1.189E-03	1.189E-03	1.189E-03
TH232	6.685E-14	1.152E-11	1.182E-11	1.213E-11	1.243E-11	1.273E-11	1.303E-11
TH234	2.413E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05
PA231	8.119E-09	9.639E-07	9.892E-07	1.014E-06	1.040E-06	1.065E-06	1.090E-06
PA233	1.757E-03	2.944E-03	2.945E-03	2.945E-03	2.945E-03	2.945E-03	2.945E-03
PA234M	9.666E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05
PA234	7.217E-05	3.233E-08	3.233E-08	3.233E-08	3.233E-08	3.233E-08	3.233E-08
U232	3.560E-06	7.155E-05	7.086E-05	7.019E-05	6.951E-05	6.885E-05	6.819E-05
U233	6.743E-08	5.560E-07	5.703E-07	5.845E-07	5.988E-07	6.130E-07	6.273E-07
U234	1.359E-04	7.558E-04	7.697E-04	7.836E-04	7.973E-04	8.109E-04	8.244E-04
U235	1.189E-03	1.189E-03	1.189E-03	1.189E-03	1.189E-03	1.189E-03	1.189E-03
U236	6.111E-03	6.111E-03	6.111E-03	6.111E-03	6.111E-03	6.111E-03	6.111E-03
U237	4.274E+04	1.303E-05	1.241E-05	1.183E-05	1.127E-05	1.075E-05	1.024E-05
U238	2.487E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05	2.487E-05
U240	3.419E-02	3.257E-12	3.257E-12	3.257E-12	3.257E-12	3.257E-12	3.257E-12
NP235	3.543E-05	1.000E-15	5.280E-16	2.786E-16	1.470E-16	7.756E-17	4.092E-17
NP236	2.912E-08	2.911E-08	2.911E-08	2.911E-08	2.911E-08	2.911E-08	2.911E-08
NP237	2.574E-03	2.944E-03	2.944E-03	2.944E-03	2.944E-03	2.944E-03	2.944E-03
NP238	7.535E+03	1.056E-07	1.052E-07	1.047E-07	1.042E-07	1.037E-07	1.032E-07
NP239	4.527E+03	6.204E-05	6.203E-05	6.203E-05	6.202E-05	6.202E-05	6.201E-05

1560 Mountain Rose
Idaho Falls, Idaho 83402

L. S. Cahn
March 22, 2005
Attachment 1

ORIGEN2 run ATR Summarized Output (Continued)

	120.0D	38.0YR	39.0YR	40.0YR	41.0YR	42.0YR	43.0YR
NP240M	3.803E+00	3.257E-12	3.257E-12	3.257E-12	3.257E-12	3.257E-12	3.257E-12
PU236	2.331E-03	2.373E-07	1.867E-07	1.469E-07	1.158E-07	9.137E-08	7.222E-08
PU238	6.163E+00	4.934E+00	4.895E+00	4.857E+00	4.819E+00	4.781E+00	4.743E+00
PU239	2.318E-02	2.438E-02	2.437E-02	2.437E-02	2.437E-02	2.437E-02	2.437E-02
PU240	2.389E-02	2.380E-02	2.380E-02	2.379E-02	2.379E-02	2.379E-02	2.379E-02
PU241	3.308E+00	5.310E-01	5.061E-01	4.823E-01	4.596E-01	4.380E-01	4.174E-01
PU242	1.570E-05	1.570E-05	1.570E-05	1.570E-05	1.570E-05	1.570E-05	1.570E-05
PU243	8.671E+00	9.586E-15	9.586E-15	9.586E-15	9.586E-15	9.586E-15	9.586E-15
PU244	3.261E-12	3.261E-12	3.261E-12	3.261E-12	3.261E-12	3.261E-12	3.261E-12
PU246	9.081E-09	2.568E-22	2.568E-22	2.568E-22	2.568E-22	2.568E-22	2.568E-22
AM241	5.617E-04	8.948E-02	9.017E-02	9.082E-02	9.143E-02	9.200E-02	9.254E-02
AM242M	2.512E-05	2.113E-05	2.103E-05	2.093E-05	2.084E-05	2.074E-05	2.065E-05
AM242	1.162E+00	2.102E-05	2.092E-05	2.083E-05	2.073E-05	2.064E-05	2.055E-05
AM243	6.160E-05	6.204E-05	6.203E-05	6.203E-05	6.202E-05	6.202E-05	6.201E-05
AM245	1.456E-05	2.311E-29	2.311E-29	2.311E-29	2.311E-29	2.311E-29	2.311E-29
AM246	9.091E-09	2.568E-22	2.568E-22	2.568E-22	2.568E-22	2.568E-22	2.568E-22
CM242	9.938E-02	1.738E-05	1.732E-05	1.725E-05	1.717E-05	1.709E-05	1.702E-05
CM243	1.267E-05	5.028E-06	4.908E-06	4.790E-06	4.675E-06	4.562E-06	4.453E-06
CM244	2.600E-03	6.085E-04	5.856E-04	5.636E-04	5.424E-04	5.221E-04	5.025E-04
CM245	1.038E-07	1.035E-07	1.035E-07	1.035E-07	1.035E-07	1.035E-07	1.035E-07
CM246	8.416E-09	8.369E-09	8.368E-09	8.367E-09	8.366E-09	8.364E-09	8.363E-09
CM247	9.586E-15	9.586E-15	9.586E-15	9.586E-15	9.586E-15	9.586E-15	9.586E-15
CM248	8.753E-15	8.753E-15	8.753E-15	8.753E-15	8.753E-15	8.752E-15	8.752E-15
CM250	1.026E-21	1.027E-21	1.027E-21	1.027E-21	1.027E-21	1.027E-21	1.027E-21
BK249	1.800E-11	1.593E-24	1.593E-24	1.593E-24	1.593E-24	1.593E-24	1.593E-24
BK250	1.642E-10	1.438E-22	1.438E-22	1.438E-22	1.438E-22	1.438E-22	1.438E-22
CF249	1.116E-15	4.315E-14	4.306E-14	4.298E-14	4.289E-14	4.281E-14	4.272E-14
CF250	1.624E-13	2.230E-14	2.115E-14	2.006E-14	1.902E-14	1.804E-14	1.711E-14
CF251	6.048E-16	5.874E-16	5.869E-16	5.865E-16	5.860E-16	5.856E-16	5.851E-16
CF252	4.855E-14	2.238E-18	1.727E-18	1.333E-18	1.029E-18	7.941E-19	6.129E-19
ES254	5.462E-18	3.825E-33	3.825E-33	3.825E-33	3.825E-33	3.825E-33	3.825E-33
H 3	5.744E+00	6.806E-01	6.435E-01	6.083E-01	5.751E-01	5.437E-01	5.141E-01
BE 10	3.663E-08	3.663E-08	3.663E-08	3.663E-08	3.663E-08	3.663E-08	3.663E-08
C 14	1.478E-06	1.471E-06	1.471E-06	1.470E-06	1.470E-06	1.470E-06	1.470E-06
SE 79	5.309E-03	5.307E-03	5.307E-03	5.307E-03	5.307E-03	5.307E-03	5.307E-03
KR 81	5.610E-10	5.610E-10	5.610E-10	5.610E-10	5.610E-10	5.610E-10	5.609E-10
KR 85	1.623E+02	1.393E+01	1.306E+01	1.224E+01	1.147E+01	1.075E+01	1.008E+01
RB 87	3.568E-07	3.569E-07	3.569E-07	3.569E-07	3.569E-07	3.569E-07	3.569E-07
SR 90	1.273E+03	5.154E+02	5.033E+02	4.915E+02	4.799E+02	4.686E+02	4.576E+02
Y 90	1.364E+03	5.156E+02	5.034E+02	4.916E+02	4.800E+02	4.687E+02	4.577E+02
ZR 93	2.724E-02	2.733E-02	2.733E-02	2.733E-02	2.733E-02	2.733E-02	2.733E-02
NB 93M	2.887E-04	2.226E-02	2.245E-02	2.262E-02	2.279E-02	2.295E-02	2.310E-02
NB 94	2.750E-07	2.747E-07	2.747E-07	2.747E-07	2.746E-07	2.746E-07	2.746E-07
TC 98	3.292E-08	3.292E-08	3.292E-08	3.292E-08	3.292E-08	3.292E-08	3.292E-08
TC 99	1.754E-01	1.795E-01	1.795E-01	1.795E-01	1.795E-01	1.795E-01	1.795E-01
RH102	3.839E-03	4.361E-07	3.434E-07	2.704E-07	2.129E-07	1.677E-07	1.320E-07
RU106	2.345E+03	1.051E-08	5.285E-09	2.657E-09	1.336E-09	6.716E-10	3.377E-10
RH106	5.004E+03	1.051E-08	5.285E-09	2.657E-09	1.336E-09	6.716E-10	3.377E-10
PD107	1.933E-04	1.933E-04	1.933E-04	1.933E-04	1.933E-04	1.933E-04	1.933E-04
AG108	5.668E-03	9.303E-11	9.253E-11	9.202E-11	9.152E-11	9.102E-11	9.053E-11
AG108M	1.286E-09	1.045E-09	1.040E-09	1.034E-09	1.028E-09	1.023E-09	1.017E-09
AG109M	1.047E+03	5.363E-16	3.108E-16	1.801E-16	1.043E-16	6.046E-17	3.506E-17
CD109	5.419E-07	5.363E-16	3.108E-16	1.801E-16	1.043E-16	6.046E-17	3.506E-17
AG110	4.487E+02	1.049E-18	3.811E-19	1.384E-19	5.006E-20	1.849E-20	6.853E-21
AG110M	4.143E+00	7.889E-17	2.866E-17	1.037E-17	3.750E-18	1.390E-18	5.153E-19
CD113M	1.793E-01	2.951E-02	2.814E-02	2.683E-02	2.559E-02	2.440E-02	2.327E-02
IN115	8.493E-14	9.470E-14	9.470E-14	9.470E-14	9.470E-14	9.470E-14	9.470E-14
SN119M	2.116E+00	1.877E-17	6.651E-18	2.357E-18	8.583E-19	2.718E-19	1.361E-19
SN121M	1.149E-03	6.782E-04	6.689E-04	6.597E-04	6.506E-04	6.416E-04	6.328E-04
TE123	2.339E-15	3.279E-15	3.279E-15	3.279E-15	3.279E-15	3.279E-15	3.279E-15
SB125	8.638E+01	6.593E-03	5.133E-03	3.997E-03	3.112E-03	2.423E-03	1.887E-03

DR WENZEL CONSULTING INC 1560 Mountain Rose

Radiological Consequence Analysis Idaho Falls, Idaho 83402

ORIGEN2 run ATR Summarized Output (Continued)

	120.0D	38.0YR	39.0YR	40.0YR	41.0YR	42.0YR	43.0YR
TE125M	1.138E+01	1.609E-03	1.252E-03	9.752E-04	7.593E-04	5.912E-04	4.603E-04
SN126	4.719E-03	4.718E-03	4.718E-03	4.718E-03	4.718E-03	4.718E-03	4.718E-03
SB126	2.281E+01	6.605E-04	6.605E-04	6.605E-04	6.605E-04	6.605E-04	6.605E-04
SB126M	9.866E+00	4.718E-03	4.718E-03	4.718E-03	4.718E-03	4.718E-03	4.718E-03
I129	2.768E-04	2.881E-04	2.881E-04	2.881E-04	2.881E-04	2.881E-04	2.881E-04
CS134	1.106E+03	3.135E-03	2.240E-03	1.601E-03	1.144E-03	8.171E-04	5.839E-04
CS135	1.158E-03	1.199E-03	1.199E-03	1.199E-03	1.199E-03	1.199E-03	1.199E-03
CS137	1.322E+03	5.495E+02	5.369E+02	5.246E+02	5.127E+02	5.010E+02	4.895E+02
BA137M	1.255E+03	5.198E+02	5.079E+02	4.963E+02	4.850E+02	4.739E+02	4.631E+02
LA138	2.399E-12	2.399E-12	2.399E-12	2.399E-12	2.399E-12	2.399E-12	2.399E-12
CE142	3.681E-07	3.683E-07	3.683E-07	3.683E-07	3.683E-07	3.683E-07	3.683E-07
CE144	3.748E+04	7.507E-11	3.081E-11	1.264E-11	5.189E-12	2.130E-12	8.739E-13
PR144	3.942E+04	7.507E-11	3.081E-11	1.264E-11	5.189E-12	2.130E-12	8.740E-13
PR144M	4.504E+02	9.009E-13	3.697E-13	1.517E-13	6.227E-14	2.555E-14	1.049E-14
ND144	5.336E-12	1.924E-11	1.924E-11	1.924E-11	1.924E-11	1.924E-11	1.924E-11
PM146	2.712E-02	2.257E-04	1.990E-04	1.754E-04	1.546E-04	1.363E-04	1.202E-04
SM146	1.541E-10	9.361E-10	9.369E-10	9.375E-10	9.382E-10	9.387E-10	9.392E-10
PM147	3.101E+03	1.542E-01	1.184E-01	9.089E-02	6.978E-02	5.358E-02	4.114E-02
SM147	4.213E-09	9.074E-08	9.074E-08	9.074E-08	9.074E-08	9.074E-08	9.074E-08
SM148	1.912E-13	2.251E-13	2.251E-13	2.251E-13	2.251E-13	2.251E-13	2.251E-13
SM149	1.199E-14	3.624E-14	3.624E-14	3.624E-14	3.624E-14	3.624E-14	3.624E-14
EU150	3.817E-08	1.837E-08	1.802E-08	1.767E-08	1.733E-08	1.700E-08	1.668E-08
SM151	4.734E+00	3.740E+00	3.711E+00	3.682E+00	3.654E+00	3.626E+00	3.598E+00
EU152	3.375E-02	4.867E-03	4.625E-03	4.395E-03	4.177E-03	3.969E-03	3.772E-03
GD152	1.336E-15	2.363E-15	2.372E-15	2.380E-15	2.388E-15	2.395E-15	2.402E-15
GD153	1.491E-01	8.119E-19	2.519E-19	1.262E-19	6.324E-20	0.000E+00	0.000E+00
EU154	5.129E+01	2.398E+00	2.213E+00	2.041E+00	1.883E+00	1.737E+00	1.603E+00
EU155	2.921E+01	1.442E-01	1.254E-01	1.090E-01	9.483E-02	8.246E-02	7.170E-02
HO166M	5.173E-07	5.061E-07	5.058E-07	5.055E-07	5.052E-07	5.049E-07	5.046E-07
TM171	5.140E-08	5.663E-14	3.947E-14	2.751E-14	1.917E-14	1.336E-14	9.313E-15

DR WENZEL CONSULTING INC
Radiological Consequence Analysis

1560 Mountain Rose
Idaho Falls, Idaho 83402

L. S. Cahn
March 22, 2005
Attachment 2

ORIGEN2 run for ZR Input

```
-1
-1
-1
  RDA     ORIGEN2, VERSION 2.1 (8-1-91) GENERIC FUEL
  BAS     PWRU FUEL
  RDA     -1 = 1 KG FUEL
  RDA     WARNING:  VECTORS ARE OFTEN CHANGED WITH RESPECT TO THEIR CONTENT.
  RDA               THESE CHANGES WILL BE NOTED ON RDA CARDS.
  CUT     -1
  LIP     0 0 0
  LIB     0  1 2 3  601  602  603   9   3   0  1   38
  TIT     INITIAL COMPOSITIONS OF UNIT AMOUNTS OF FUEL AND STRUCT MAT'LS
  RDA     READ FUEL COMPOSITION INCLUDING IMPURITIES
  INP     -1   1  -1  -1  1  1
  TIT     IRRADIATION OF GENERIC FUEL
  MOV     -1   1   0   1.0
  HED      1                                                     CHARGE
  BUP
  IRP     100.0    .2577   1    2    4 2
  IRP     200.0    .2577   2    3    4 0
  IRP     400.0    .2577   3    4    4 0
  IRP     600.0    .2577   4    5    4 0
  IRP     800.0    .2577   5    6    4 0
  IRP    1000.0    .2577   6    7    4 0
  IRP    1200.0    .2577   7    8    4 0
  IRP    1400.0    .2577   8    9    4 0
  IRP    1600.0    .2577   9   10    4 0
  IRP    1800.0    .2577  10   11    4 0
  IRP    1826.0    .2577  11   12    4 0
  BUP
  OPTL    8 8 8 8 5   8 5 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTA    8 8 8 8 5   8 5 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTF    8 8 8 8 5   8 5 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  MOV       12      1    0  1.0
  DEC      35.      1    2    5    4
  DEC      36.      2    3    5    0
  DEC      37.      3    4    5    0
  DEC      38.      4    5    5    0
  DEC      39.      5    6    5    0
  DEC      40.      6    7    5    0
  DEC      41.      7    8    5    0
  DEC      42.      8    9    5    0
  OUT      -9     1     -1     0
  OUT       9     1     -1     0
  END
  2   922350   1000.0 922360   .4366  922380  8.6636       0     0.0    FUEL 97%
  1    60120   .92669  60130 .01031        0 .0           0      .0    C
  1    70140   1.2454  70150 .00463        0 .0           0      .0    N
  1    80160   74.720  80170 .02996   80180 0.1498        0      .0    O
  1   130270   1.2500      0 .0            0 .0           0      .0    Al
  1   220460   .04992 220470 .04555  220480 .46051  220490 .03432    Ti
  1   220500   .03370      0 .0            0 .0           0      .0
  1   240500   2.7113 240520 52.285  240530 5.9280  240540 1.4758    Cr
  1   260540   5.5283 260560 85.942  260570 1.9677  260580 .26236    Fe
  1   280580   21.300 280600 8.1432  280610 .35256  280620 1.1201    Ni
```

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Idaho Falls, Idaho 83402

ORIGEN2 run for ZR Input (Continued)

```
  1    280640  .28392       0 .0          0 .0          0     .0
  1    400900  31494. 400910 6866.6  400920 10496.  400940 10637.    Zr
  1    400960  1713.6       0 .0          0 .0          0     .0
  1    410930  6.2400       0 .0          0 .0          0     .0    Nb
  1    501120  9.4187 501140 6.3115  501150 3.4956  501160 141.09    Sn
  1    501170  74.573 501180 235.18  501190 83.312  501200 316.45
  1    501220  44.957 501240 56.221       0 .0          0 .0
  1    721740  .02025 721760 .65075  721770 2.3258  721780 3.4121    Hf
  1    721790  1.7036 721800 4.3875       0 .0          0 .0
  1    731801  .00007 731810 .62393       0 .0          0 .0         Ta
  0
```

ORIGEN2 run ZR BAT File

```
echo off
echo **                                                               **
echo **                          O R I G E N 2                        **
echo **                                                               **
copy zr.INP tape5.inp >nul
REM  (NOT USED IN THIS CASE) copy zr.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\pwrus.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
echo finished with origen2 calculation
rem  combine and save files from run
copy tape12.out+tape6.out zr.u6 >nul
copy tape13.out+tape11.out zr.u11 >nul
ren tape7.out zr.pch
ren tape15.out zr.dbg
ren tape16.out zr.vxs
ren tape50.out zr.ech
rem  cleanup files
del tape*.inp
del tape*.out
echo ****************************************************************************
echo ******************* O R I G E N 2 - Version 2.1 ***********************
echo *********************** Execution Completed **************************
echo ****************************************************************************
echo on
```

ORIGEN2 run ZR Summarized Output

	1826.0D	35.0YR	36.0YR	37.0YR	38.0YR	39.0YR	40.0YR	41.0YR	42.0YR
H 3	7.812E-07	1.095E-07	1.036E-07	9.791E-08	9.256E-08	8.751E-08	8.273E-08	7.822E-08	7.395E-08
BE 10	1.753E-09	1.753E-09	1.753E-09	1.753E-09	1.753E-09	1.753E-09	1.753E-09	1.753E-09	1.753E-09
C 14	1.480E-02	1.474E-02	1.473E-02	1.473E-02	1.473E-02	1.473E-02	1.473E-02	1.473E-02	1.472E-02
SI 32	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22
P 32	3.414E-16	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22	2.076E-22
AR 39	5.144E-19	4.701E-19	4.689E-19	4.677E-19	4.665E-19	4.653E-19	4.641E-19	4.629E-19	4.617E-19
AR 42	5.691E-19	2.738E-19	2.680E-19	2.624E-19	2.569E-19	2.515E-19	2.462E-19	2.410E-19	2.360E-19
K 42	6.710E-12	2.738E-19	2.681E-19	2.625E-19	2.569E-19	2.515E-19	2.463E-19	2.411E-19	2.360E-19
V 50	3.917E-17	3.917E-17	3.917E-17	3.917E-17	3.917E-17	3.917E-17	3.917E-17	3.917E-17	3.917E-17
MN 54	2.934E+00	1.422E-12	6.326E-13	2.814E-13	1.252E-13	5.567E-14	2.476E-14	1.101E-14	4.899E-15
FE 55	2.704E+01	2.397E-03	1.836E-03	1.406E-03	1.077E-03	8.251E-04	6.320E-04	4.841E-04	3.708E-04
CO 60	1.430E-01	1.432E-03	1.255E-03	1.101E-03	9.650E-04	8.460E-04	7.418E-04	6.503E-04	5.702E-04
NI 59	8.585E-03	8.582E-03	8.582E-03	8.582E-03	8.582E-03	8.582E-03	8.582E-03	8.582E-03	8.582E-03
NI 63	1.298E+00	9.968E-01	9.893E-01	9.819E-01	9.745E-01	9.672E-01	9.599E-01	9.527E-01	9.456E-01
ZN 65	6.260E-07	1.038E-22	1.038E-22	1.038E-22	1.038E-22	1.038E-22	1.038E-22	1.038E-22	1.038E-22
SR 90	2.107E-04	9.161E-05	8.946E-05	8.735E-05	8.530E-05	8.329E-05	8.133E-05	7.942E-05	7.755E-05
Y 90	1.788E+02	9.164E-05	8.948E-05	8.738E-05	8.532E-05	8.331E-05	8.135E-05	7.944E-05	7.757E-05
ZR 93	4.609E-02	4.608E-02	4.608E-02	4.608E-02	4.608E-02	4.608E-02	4.608E-02	4.608E-02	4.608E-02
NB 93M	4.412E-03	3.717E-02	3.750E-02	3.781E-02	3.810E-02	3.839E-02	3.865E-02	3.891E-02	3.915E-02
NB 94	7.379E-03	7.370E-03	7.370E-03	7.369E-03	7.369E-03	7.369E-03	7.369E-03	7.368E-03	7.368E-03
TC 98	3.276E-14	3.276E-14	3.276E-14	3.276E-14	3.276E-14	3.276E-14	3.276E-14	3.276E-14	3.276E-14
TC 99	3.751E-07	3.792E-07	3.792E-07	3.792E-07	3.792E-07	3.792E-07	3.792E-07	3.792E-07	3.792E-07
RU106	4.717E-26	1.664E-36	1.664E-36	1.664E-36	1.664E-36	1.664E-36	1.664E-36	1.664E-36	1.664E-36
RH102	1.908E-19	4.440E-23	4.440E-23	4.440E-23	4.440E-23	4.440E-23	4.440E-23	4.440E-23	4.440E-23
PD107	8.267E-36	1.850E-35	1.850E-35	1.850E-35	1.850E-35	1.850E-35	1.850E-35	1.850E-35	1.850E-35
IN115	7.812E-18	7.908E-18	7.908E-18	7.908E-18	7.908E-18	7.908E-18	7.908E-18	7.908E-18	7.908E-18
SN119M	6.755E+02	1.330E-13	4.732E-14	1.684E-14	5.992E-15	2.132E-15	7.588E-16	2.700E-16	9.606E-17
SN121M	9.142E-02	5.626E-02	5.548E-02	5.472E-02	5.397E-02	5.322E-02	5.249E-02	5.177E-02	5.105E-02
SB125	2.197E+02	3.491E-02	2.718E-02	2.116E-02	1.648E-02	1.283E-02	9.990E-03	7.778E-03	6.056E-03
TE123	3.299E-14	3.775E-14	3.775E-14	3.775E-14	3.775E-14	3.775E-14	3.775E-14	3.775E-14	3.775E-14
TE125M	4.782E+01	8.518E-03	6.632E-03	5.164E-03	4.021E-03	3.131E-03	2.437E-03	1.898E-03	1.478E-03
I129	4.661E-16	4.687E-16	4.687E-16	4.687E-16	4.687E-16	4.687E-16	4.687E-16	4.687E-16	4.687E-16
CS134	1.294E-18	1.006E-23	1.006E-23	1.006E-23	1.006E-23	1.006E-23	1.006E-23	1.006E-23	1.006E-23
CS135	4.746E-33	2.159E-32	2.159E-32	2.159E-32	2.159E-32	2.159E-32	2.159E-32	2.159E-32	2.159E-32
CS137	6.001E-38	5.807E-37	5.807E-37	5.807E-37	5.807E-37	5.807E-37	5.807E-37	5.807E-37	5.807E-37
BA133	5.173E-32	1.012E-31	1.012E-31	1.012E-31	1.012E-31	1.012E-31	1.012E-31	1.012E-31	1.012E-31
TM171	6.465E-17	2.107E-22	2.107E-22	2.107E-22	2.107E-22	2.107E-22	2.107E-22	2.107E-22	2.107E-22
LU176	1.328E-11	1.328E-11	1.328E-11	1.328E-11	1.328E-11	1.328E-11	1.328E-11	1.328E-11	1.328E-11
HF182	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08
TA182	5.959E+01	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08	5.745E-08
RE187	1.287E-16	1.296E-16	1.296E-16	1.296E-16	1.296E-16	1.296E-16	1.296E-16	1.296E-16	1.296E-16
OS194	1.954E-24	1.954E-24	1.954E-24	1.954E-24	1.954E-24	1.954E-24	1.954E-24	1.954E-24	1.954E-24
IR192	5.601E-14	3.842E-20	3.842E-20	3.842E-20	3.842E-20	3.842E-20	3.842E-20	3.842E-20	3.842E-20
IR192M	4.244E-20	3.838E-20	3.838E-20	3.838E-20	3.838E-20	3.838E-20	3.838E-20	3.838E-20	3.838E-20
IR194	4.132E-16	1.954E-24	1.955E-24	1.955E-24	1.955E-24	1.955E-24	1.955E-24	1.955E-24	1.955E-24
PT193	9.494E-20	9.132E-20	9.120E-20	9.107E-20	9.095E-20	9.082E-20	9.069E-20	9.057E-20	9.044E-20
TL206	4.844E-21	4.844E-21	4.844E-21	4.844E-21	4.844E-21	4.844E-21	4.844E-21	4.844E-21	4.844E-21
TL207	7.215E-09	3.133E-07	3.271E-07	3.405E-07	3.540E-07	3.676E-07	3.814E-07	3.954E-07	4.095E-07
TL208	6.998E-06	5.985E-05	5.950E-05	5.893E-05	5.837E-05	5.781E-05	5.725E-05	5.671E-05	5.616E-05
TL209	4.390E-11	4.625E-11	4.789E-11	4.958E-11	5.131E-11	5.310E-11	5.493E-11	5.680E-11	5.873E-11
PB209	2.037E-09	2.141E-09	2.217E-09	2.295E-09	2.376E-09	2.458E-09	2.543E-09	2.630E-09	2.719E-09
PB210	6.560E-12	4.631E-10	5.094E-10	5.589E-10	6.118E-10	6.683E-10	7.283E-10	7.922E-10	8.599E-10
PB211	7.235E-09	3.142E-07	3.280E-07	3.414E-07	3.550E-07	3.687E-07	3.825E-07	3.965E-07	4.106E-07
PB212	1.948E-05	1.666E-04	1.656E-04	1.640E-04	1.624E-04	1.609E-04	1.594E-04	1.578E-04	1.563E-04
PB214	2.127E-12	1.904E-09	2.053E-09	2.209E-09	2.373E-09	2.544E-09	2.724E-09	2.911E-09	3.106E-09
BI208	5.624E-21	5.623E-21	5.623E-21	5.623E-21	5.623E-21	5.623E-21	5.623E-21	5.623E-21	5.623E-21
BI210M	4.863E-21	4.863E-21	4.863E-21	4.863E-21	4.863E-21	4.863E-21	4.863E-21	4.863E-21	4.863E-21
BI210	6.481E-12	4.631E-10	5.096E-10	5.592E-10	6.122E-10	6.686E-10	7.287E-10	7.926E-10	8.604E-10
BI211	7.235E-09	3.142E-07	3.280E-07	3.414E-07	3.550E-07	3.687E-07	3.825E-07	3.965E-07	4.106E-07
BI212	1.948E-05	1.666E-04	1.656E-04	1.640E-04	1.624E-04	1.609E-04	1.594E-04	1.578E-04	1.563E-04
BI213	2.032E-09	2.141E-09	2.217E-09	2.295E-09	2.376E-09	2.458E-09	2.543E-09	2.630E-09	2.719E-09
BI214	2.127E-12	1.904E-09	2.053E-09	2.209E-09	2.373E-09	2.544E-09	2.724E-09	2.911E-09	3.106E-09
PO210	4.211E-12	4.631E-10	4.829E-10	5.262E-10	5.760E-10	6.298E-10	6.872E-10	7.482E-10	8.130E-10
PO211	2.026E-11	8.796E-10	9.185E-10	9.560E-10	9.939E-10	1.032E-09	1.071E-09	1.110E-09	1.150E-09
PO212	1.248E-05	1.067E-04	1.061E-04	1.051E-04	1.041E-04	1.031E-04	1.021E-04	1.011E-04	1.002E-04
PO213	1.988E-09	2.095E-09	2.169E-09	2.246E-09	2.324E-09	2.405E-09	2.488E-09	2.573E-09	2.660E-09
PO214	2.076E-10	1.903E-09	2.052E-09	2.208E-09	2.372E-09	2.544E-09	2.723E-09	2.910E-09	3.106E-09
PO215	7.235E-09	3.142E-07	3.280E-07	3.414E-07	3.550E-07	3.687E-07	3.825E-07	3.965E-07	4.106E-07
PO216	1.948E-05	1.666E-04	1.656E-04	1.640E-04	1.624E-04	1.609E-04	1.594E-04	1.578E-04	1.563E-04
PO218	2.127E-12	1.904E-09	2.053E-09	2.209E-09	2.373E-09	2.545E-09	2.724E-09	2.911E-09	3.107E-09

ORIGEN2 run ZR Summarized Output (Continued)

	1826.0D	35.0YR	36.0YR	37.0YR	38.0YR	39.0YR	40.0YR	41.0YR	42.0YR
AT217	2.032E-09	2.141E-09	2.217E-09	2.295E-09	2.376E-09	2.458E-09	2.543E-09	2.630E-09	2.719E-09
RN219	7.235E-09	3.142E-07	3.280E-07	3.414E-07	3.550E-07	3.687E-07	3.825E-07	3.965E-07	4.106E-07
RN220	1.948E-05	1.666E-04	1.656E-04	1.640E-04	1.624E-04	1.609E-04	1.594E-04	1.578E-04	1.563E-04
RN222	2.127E-12	1.904E-09	2.053E-09	2.209E-09	2.373E-09	2.545E-09	2.724E-09	2.911E-09	3.107E-09
FR221	2.032E-09	2.141E-09	2.217E-09	2.295E-09	2.376E-09	2.458E-09	2.543E-09	2.630E-09	2.719E-09
FR223	1.004E-10	4.335E-09	4.517E-09	4.702E-09	4.888E-09	5.077E-09	5.267E-09	5.460E-09	5.654E-09
RA223	7.235E-09	3.142E-07	3.280E-07	3.414E-07	3.550E-07	3.687E-07	3.825E-07	3.965E-07	4.106E-07
RA224	1.948E-05	1.666E-04	1.656E-04	1.640E-04	1.624E-04	1.609E-04	1.594E-04	1.578E-04	1.563E-04
RA225	2.087E-09	2.141E-09	2.217E-09	2.295E-09	2.376E-09	2.458E-09	2.543E-09	2.630E-09	2.719E-09
RA226	2.146E-12	1.904E-09	2.053E-09	2.209E-09	2.373E-09	2.545E-09	2.724E-09	2.911E-09	3.107E-09
RA228	1.285E-13	9.218E-12	9.540E-12	9.862E-12	1.019E-11	1.051E-11	1.083E-11	1.116E-11	1.148E-11
AC225	2.032E-09	2.141E-09	2.217E-09	2.295E-09	2.376E-09	2.458E-09	2.543E-09	2.630E-09	2.719E-09
AC227	7.278E-09	3.141E-07	3.273E-07	3.407E-07	3.542E-07	3.679E-07	3.817E-07	3.956E-07	4.097E-07
AC228	5.130E-08	9.218E-12	9.541E-12	9.863E-12	1.019E-11	1.051E-11	1.083E-11	1.116E-11	1.148E-11
TH227	7.136E-09	3.098E-07	3.235E-07	3.367E-07	3.501E-07	3.636E-07	3.772E-07	3.910E-07	4.049E-07
TH228	1.967E-05	1.666E-04	1.650E-04	1.634E-04	1.618E-04	1.603E-04	1.588E-04	1.572E-04	1.557E-04
TH229	7.115E-10	2.141E-09	2.217E-09	2.295E-09	2.376E-09	2.458E-09	2.543E-09	2.630E-09	2.719E-09
TH230	3.041E-09	3.374E-07	3.543E-07	3.717E-07	3.894E-07	4.075E-07	4.260E-07	4.448E-07	4.640E-07
TH231	9.064E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04
TH232	8.375E-13	1.232E-11	1.265E-11	1.298E-11	1.331E-11	1.364E-11	1.397E-11	1.429E-11	1.462E-11
TH234	2.889E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06
PA231	8.558E-08	7.258E-07	7.442E-07	7.626E-07	7.809E-07	7.993E-07	8.176E-07	8.360E-07	8.544E-07
PA233	4.612E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03
PA234M	3.337E-05	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06
PA234	3.061E-05	3.744E-09	3.744E-09	3.744E-09	3.744E-09	3.744E-09	3.744E-09	3.744E-09	3.744E-09
U232	6.530E-05	1.622E-04	1.606E-04	1.591E-04	1.576E-04	1.560E-04	1.546E-04	1.531E-04	1.516E-04
U233	7.026E-08	7.949E-07	8.178E-07	8.408E-07	8.637E-07	8.866E-07	9.095E-07	9.324E-07	9.553E-07
U234	1.786E-04	1.866E-03	1.908E-03	1.949E-03	1.990E-03	2.031E-03	2.071E-03	2.111E-03	2.151E-03
U235	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04	8.650E-04
U236	6.653E-03	6.653E-03	6.653E-03	6.653E-03	6.653E-03	6.653E-03	6.653E-03	6.653E-03	6.653E-03
U237	9.421E+03	4.091E-06	3.899E-06	3.716E-06	3.541E-06	3.375E-06	3.216E-06	3.065E-06	2.921E-06
U238	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06	2.880E-06
U240	5.196E-05	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13
NP235	4.563E-05	8.768E-15	4.627E-15	2.442E-15	1.288E-15	6.799E-16	3.588E-16	1.893E-16	9.990E-17
NP236	4.940E-08	4.939E-08	4.939E-08	4.939E-08	4.939E-08	4.939E-08	4.939E-08	4.939E-08	4.939E-08
NP237	4.654E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03	4.736E-03
NP238	2.425E+03	4.174E-07	4.155E-07	4.136E-07	4.117E-07	4.098E-07	4.080E-07	4.061E-07	4.043E-07
NP239	8.563E+01	2.291E-05	2.291E-05	2.291E-05	2.290E-05	2.290E-05	2.290E-05	2.290E-05	2.290E-05
NP240M	1.081E-02	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13	2.244E-13
PU236	3.906E-03	7.954E-07	6.247E-07	4.908E-07	3.858E-07	3.035E-07	2.390E-07	1.884E-07	1.487E-07
PU238	1.931E+01	1.477E+01	1.465E+01	1.454E+01	1.442E+01	1.431E+01	1.419E+01	1.408E+01	1.397E+01
PU239	1.003E-02	1.004E-02	1.004E-02	1.004E-02	1.004E-02	1.004E-02	1.004E-02	1.004E-02	1.004E-02
PU240	7.658E-03	7.632E-03	7.631E-03	7.631E-03	7.630E-03	7.629E-03	7.628E-03	7.628E-03	7.627E-03
PU241	8.992E-01	1.668E-01	1.589E-01	1.515E-01	1.444E-01	1.376E-01	1.311E-01	1.249E-01	1.191E-01
PU242	4.641E-06	4.642E-06	4.642E-06	4.642E-06	4.642E-06	4.642E-06	4.642E-06	4.642E-06	4.642E-06
PU243	3.981E-01	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14
PU244	2.246E-13	2.247E-13	2.247E-13	2.247E-13	2.247E-13	2.247E-13	2.247E-13	2.247E-13	2.247E-13
PU246	1.968E-11	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23
AM241	1.053E-03	2.455E-02	2.477E-02	2.498E-02	2.517E-02	2.536E-02	2.553E-02	2.570E-02	2.585E-02
AM242M	9.791E-05	8.347E-05	8.309E-05	8.271E-05	8.234E-05	8.196E-05	8.159E-05	8.122E-05	8.085E-05
AM242	2.537E-01	8.305E-05	8.268E-05	8.230E-05	8.192E-05	8.155E-05	8.118E-05	8.081E-05	8.044E-05
AM243	2.296E-05	2.291E-05	2.291E-05	2.291E-05	2.290E-05	2.290E-05	2.290E-05	2.290E-05	2.290E-05
AM245	1.506E-07	4.535E-28	4.534E-28	4.534E-28	4.534E-28	4.534E-28	4.534E-28	4.534E-28	4.534E-28
AM246	1.968E-11	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23	7.470E-23
CM242	1.174E-01	6.868E-05	6.845E-05	6.815E-05	6.785E-05	6.754E-05	6.723E-05	6.693E-05	6.662E-05
CM243	2.912E-05	1.243E-05	1.213E-05	1.184E-05	1.156E-05	1.128E-05	1.101E-05	1.074E-05	1.049E-05
CM244	1.315E-03	3.444E-04	3.315E-04	3.191E-04	3.071E-04	2.955E-04	2.844E-04	2.738E-04	2.635E-04
CM245	6.304E-08	6.286E-08	6.286E-08	6.285E-08	6.285E-08	6.284E-08	6.283E-08	6.283E-08	6.282E-08
CM246	6.789E-09	6.754E-09	6.753E-09	6.752E-09	6.751E-09	6.750E-09	6.749E-09	6.748E-09	6.747E-09
CM247	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14	1.067E-14
CM248	1.464E-14	1.464E-14	1.464E-14	1.464E-14	1.464E-14	1.464E-14	1.464E-14	1.464E-14	1.464E-14
CM250	2.974E-22	2.988E-22	2.988E-22	2.988E-22	2.988E-22	2.988E-22	2.988E-22	2.988E-22	2.988E-22
BK249	3.309E-11	3.127E-23	3.127E-23	3.127E-23	3.127E-23	3.127E-23	3.127E-23	3.127E-23	3.127E-23
BK250	4.778E-11	4.183E-23	4.183E-23	4.183E-23	4.183E-23	4.183E-23	4.183E-23	4.183E-23	4.183E-23
CF249	1.589E-14	9.229E-14	9.211E-14	9.193E-14	9.175E-14	9.157E-14	9.139E-14	9.120E-14	9.102E-14
CF250	3.729E-13	5.857E-14	5.555E-14	5.268E-14	4.996E-14	4.738E-14	4.494E-14	4.262E-14	4.042E-14
CF251	1.679E-15	1.634E-15	1.633E-15	1.632E-15	1.630E-15	1.629E-15	1.628E-15	1.627E-15	1.625E-15
CF252	1.729E-13	1.753E-17	1.348E-17	1.036E-17	7.965E-18	6.123E-18	4.707E-18	3.618E-18	2.792E-18
ES254	4.326E-17	4.763E-31	4.763E-31	4.763E-31	4.763E-31	4.763E-31	4.763E-31	4.763E-31	4.763E-31

ORIGEN2 run ZR Summarized Output (Continued)

	1826.0D	35.0YR	36.0YR	37.0YR	38.0YR	39.0YR	40.0YR	41.0YR	42.0YR
H 3	5.806E+00	8.140E-01	7.696E-01	7.276E-01	6.879E-01	6.503E-01	6.148E-01	5.813E-01	5.495E-01
BE 10	4.196E-08	4.196E-08	4.196E-08	4.196E-08	4.196E-08	4.196E-08	4.196E-08	4.196E-08	4.196E-08
C 14	1.692E-06	1.685E-06	1.685E-06	1.684E-06	1.684E-06	1.684E-06	1.684E-06	1.684E-06	1.683E-06
SE 79	6.079E-03	6.077E-03	6.077E-03	6.077E-03	6.077E-03	6.076E-03	6.076E-03	6.076E-03	6.076E-03
KR 81	8.776E-10	8.775E-10	8.775E-10	8.775E-10	8.775E-10	8.775E-10	8.775E-10	8.775E-10	8.775E-10
KR 85	1.616E+02	1.681E+01	1.576E+01	1.477E+01	1.385E+01	1.298E+01	1.217E+01	1.141E+01	1.069E+01
RB 87	4.092E-07	4.092E-07	4.092E-07	4.092E-07	4.092E-07	4.092E-07	4.092E-07	4.092E-07	4.092E-07
SR 90	1.382E+03	6.009E+02	5.867E+02	5.729E+02	5.595E+02	5.463E+02	5.334E+02	5.209E+02	5.086E+02
Y 90	1.412E+03	6.010E+02	5.869E+02	5.731E+02	5.596E+02	5.464E+02	5.336E+02	5.210E+02	5.088E+02
ZR 93	3.125E-02	3.126E-02	3.126E-02	3.126E-02	3.126E-02	3.126E-02	3.126E-02	3.126E-02	3.126E-02
NB 93M	3.505E-03	2.530E-02	2.551E-02	2.572E-02	2.592E-02	2.611E-02	2.628E-02	2.645E-02	2.662E-02
NB 94	3.100E-07	3.097E-07	3.097E-07	3.096E-07	3.096E-07	3.096E-07	3.096E-07	3.096E-07	3.096E-07
TC 98	3.974E-08	3.974E-08	3.974E-08	3.974E-08	3.974E-08	3.974E-08	3.974E-08	3.974E-08	3.974E-08
TC 99	1.950E-01	1.955E-01	1.955E-01	1.955E-01	1.955E-01	1.955E-01	1.955E-01	1.955E-01	1.955E-01
RH102	6.436E-03	1.498E-06	1.179E-06	9.287E-07	7.313E-07	5.758E-07	4.534E-07	3.570E-07	2.811E-07
RU106	8.686E+02	3.065E-08	1.541E-08	7.746E-09	3.895E-09	1.958E-09	9.844E-10	4.949E-10	2.488E-10
RH106	9.317E+02	3.065E-08	1.541E-08	7.746E-09	3.895E-09	1.958E-09	9.844E-10	4.949E-10	2.488E-10
PD107	2.178E-04	2.178E-04	2.178E-04	2.178E-04	2.178E-04	2.178E-04	2.178E-04	2.178E-04	2.178E-04
AG108	7.020E-04	5.900E-10	5.868E-10	5.836E-10	5.804E-10	5.773E-10	5.741E-10	5.710E-10	5.679E-10
AG108M	8.025E-09	6.630E-09	6.593E-09	6.558E-09	6.522E-09	6.486E-09	6.451E-09	6.416E-09	6.381E-09
AG109M	1.335E+02	2.971E-15	1.721E-15	9.975E-16	5.780E-16	3.350E-16	1.941E-16	1.125E-16	6.517E-17
CD109	5.841E-07	2.971E-15	1.721E-15	9.975E-16	5.780E-16	3.349E-16	1.941E-16	1.125E-16	6.516E-17
AG110	7.834E+01	1.358E-17	4.932E-18	1.790E-18	6.503E-19	2.362E-19	8.577E-20	3.103E-20	1.146E-20
AG110M	2.567E+00	1.021E-15	3.708E-16	1.346E-16	4.890E-17	1.776E-17	6.426E-18	2.325E-18	8.616E-19
CD113M	1.906E-01	3.615E-02	3.447E-02	3.287E-02	3.134E-02	2.989E-02	2.850E-02	2.718E-02	2.592E-02
IN115	6.915E-14	7.032E-14	7.032E-14	7.032E-14	7.032E-14	7.032E-14	7.032E-14	7.032E-14	7.032E-14
SN119M	6.374E-01	1.255E-16	4.468E-17	1.591E-17	5.638E-18	1.998E-18	7.277E-19	2.305E-19	1.154E-19
SN121M	1.275E-03	7.844E-04	7.736E-04	7.629E-04	7.524E-04	7.420E-04	7.318E-04	7.217E-04	7.118E-04
TE123	6.391E-15	7.289E-15	7.289E-15	7.289E-15	7.289E-15	7.289E-15	7.289E-15	7.289E-15	7.289E-15
SB125	6.065E+01	9.578E-03	7.458E-03	5.807E-03	4.521E-03	3.520E-03	2.741E-03	2.134E-03	1.662E-03
TE125M	1.365E+01	2.337E-03	1.820E-03	1.417E-03	1.103E-03	8.589E-04	6.687E-04	5.207E-04	4.054E-04
SN126	5.393E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03
SB126	3.027E+00	7.548E-04	7.548E-04	7.548E-04	7.548E-04	7.548E-04	7.548E-04	7.548E-04	7.548E-04
SB126M	1.161E+00	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03	5.391E-03
I129	3.241E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04	3.254E-04
CS134	1.455E+03	1.130E-02	8.073E-03	5.768E-03	4.122E-03	2.945E-03	2.104E-03	1.503E-03	1.074E-03
CS135	1.047E-02	1.048E-02	1.048E-02	1.048E-02	1.048E-02	1.048E-02	1.048E-02	1.048E-02	1.048E-02
CS137	1.437E+03	6.401E+02	6.255E+02	6.112E+02	5.973E+02	5.836E+02	5.703E+02	5.573E+02	5.445E+02
BA137M	1.360E+03	6.056E+02	5.917E+02	5.782E+02	5.650E+02	5.521E+02	5.395E+02	5.272E+02	5.151E+02
LA138	2.631E-12	2.631E-12	2.631E-12	2.631E-12	2.631E-12	2.631E-12	2.631E-12	2.631E-12	2.631E-12
CE142	4.183E-07	4.183E-07	4.183E-07	4.183E-07	4.183E-07	4.183E-07	4.183E-07	4.183E-07	4.183E-07
CE144	1.145E+04	3.318E-10	1.362E-10	5.589E-11	2.294E-11	9.413E-12	3.863E-12	1.585E-12	6.506E-13
PR144	1.149E+04	3.318E-10	1.362E-10	5.589E-11	2.294E-11	9.413E-12	3.863E-12	1.585E-12	6.506E-13
PR144M	1.375E+02	3.982E-12	1.634E-12	6.707E-13	2.752E-13	1.130E-13	4.636E-14	1.902E-14	7.808E-15
ND144	1.939E-11	2.363E-11	2.363E-11	2.363E-11	2.363E-11	2.363E-11	2.363E-11	2.363E-11	2.363E-11
PM146	2.209E-02	2.683E-04	2.365E-04	2.085E-04	1.838E-04	1.620E-04	1.429E-04	1.259E-04	1.110E-04
SM146	2.861E-09	3.496E-09	3.497E-09	3.497E-09	3.498E-09	3.499E-09	3.499E-09	3.500E-09	3.500E-09
PM147	1.949E+03	1.933E-01	1.484E-01	1.139E-01	8.749E-02	6.718E-02	5.158E-02	3.960E-02	3.041E-02
SM147	4.213E-08	9.128E-08	9.128E-08	9.129E-08	9.129E-08	9.129E-08	9.129E-08	9.129E-08	9.129E-08
SM148	6.979E-13	7.065E-13	7.065E-13	7.065E-13	7.065E-13	7.065E-13	7.065E-13	7.065E-13	7.065E-13
SM149	6.754E-15	8.921E-15	8.921E-15	8.921E-15	8.921E-15	8.921E-15	8.921E-15	8.921E-15	8.921E-15
EU150	3.005E-07	1.532E-07	1.502E-07	1.474E-07	1.446E-07	1.418E-07	1.391E-07	1.364E-07	1.338E-07
SM151	4.307E+00	3.315E+00	3.289E+00	3.264E+00	3.239E+00	3.214E+00	3.189E+00	3.165E+00	3.141E+00
EU152	2.107E-01	3.539E-02	3.364E-02	3.196E-02	3.038E-02	2.887E-02	2.743E-02	2.607E-02	2.477E-02
GD152	2.421E-14	3.037E-14	3.043E-14	3.049E-14	3.054E-14	3.059E-14	3.065E-14	3.069E-14	3.074E-14
GD153	1.527E-01	1.918E-17	6.707E-18	2.346E-18	8.448E-19	2.621E-19	1.313E-19	6.581E-20	0.000E+00
EU154	6.988E+01	4.162E+00	3.839E+00	3.542E+00	3.268E+00	3.015E+00	2.781E+00	2.566E+00	2.367E+00
EU155	3.712E+01	2.787E-01	2.423E-01	2.107E-01	1.832E-01	1.593E-01	1.385E-01	1.205E-01	1.048E-01
HO166M	8.309E-07	8.143E-07	8.138E-07	8.133E-07	8.129E-07	8.124E-07	8.119E-07	8.114E-07	8.110E-07
TM171	6.258E-08	2.036E-13	1.419E-13	9.892E-14	6.895E-14	4.805E-14	3.349E-14	2.334E-14	1.627E-14

DR WENZEL CONSULTING INC

Radiological Consequence Analysis

1560 Mountain Rose

Idaho Falls, Idaho 83402

ORIGEN2 run MK_I Input

```
-1
-1
-1
  RDA     ORIGEN2, VERSION 2.1 (8-1-91) EBR-II Mk-I
  BAS     ONE SUBASSEMBLY
  CUT     -1
  LIP     0 0 0
  LIB     0  1 2 3  381  382  383   9   50  0  4  0
  TIT     EBR-II Mk-I SUBASSEMBLY
  PHO     101  102  103  10
  INP     -1   1  -1  -1  1  1
  MOV     -1   1   0   1.0
  HED      1                                              ELEMENT
  BUP
  IRP      50.0   .1480   1   2   4 2
  IRP     100.0   .1480   2   3   4 0
  IRP     200.0   .1480   3   4   4 0
  IRP     250.0   .1480   4   5   4 0
  IRP     300.0   .1480   5   6   4 0
  IRP     345.0   .1480   6   7   4 0
  BUP
  OPTL    8 8 8 8 5   8 5 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTA    5 5 5 5 5   8 5 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTF    8 8 8 8 5   8 5 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  MOV      7    1    0   1.0
  DEC      35.    1   2   5   4
  DEC      36.    2   3   5   0
  DEC      37.    3   4   5   0
  DEC      38.    4   5   5   0
  DEC      39.    5   6   5   0
  DEC      40.    6   7   5   0
  OUT      -7    1     -1     0
  OUT       7    1     -1     0
  END
  2   922340 29.57    922350 2950.    922360 5.314    922380 2635.    FUEL 52.5%
  1    60120 1.74E+1   60130 1.94E-1 140280 2.23E+2 140290 1.05E+1 SS (22695 g)
  1   140300 6.96E+0 150310 9.94E+0 160320 8.78E+0 160330 4.99E-3 FISSIUM
  1   160340 2.80E-1 160360 1.33E-3 240500 1.64E+2 240520 3.15E+3  (300 g)
  1   240530 8.50E+2 240540 8.91E+1 250255 4.43E+2 260540 8.55E+2
  1   260560 1.33E+4 260570 3.04E+2 260580 4.06E+1 280580 1.81E+3
  1   280600 6.96E+1 280610 3.01E+1 280620 9.57E+1 280640 2.42E+1
  1   400900 2.63E+0 400910 5.71E-1 400920 8.74E-1 400940 8.85E-1
  1   400960 1.43E-1 420920 1.04E+2 420940 6.45E+1 420950 1.11E+2
  1   420960 1.17E+2 420970 6.67E+1 420980 1.68E+2 421000 67.2E+1
  1   440960 6.44E+0 440980 2.17E+0 440990 1.48E+1 441000 1.47E+1
  1   441010 1.99E+1 441020 3.68E+1 441040 2.17E+1 451030 1.68E+1
  1   912310 1.14E+1       0 0.00E+0       0 0.00E+0       0 0.00E+0
  0
```

DR WENZEL CONSULTING INC
1560 Mountain Rose
Radiological Consequence Analysis
Idaho Falls, Idaho 83402

ORIGEN2 run MK_I BAT File

```
echo off
echo **                                                                    **
echo **                          O R I G E N 2                             **
echo **                                                                    **
copy mk_i.INP tape5.inp >nul
REM  (NOT USED IN THIS CASE) copy mk_i.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\fftfc.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
echo finished with origen2 calculation
rem  combine and save files from run
copy tape12.out+tape6.out mk_i.u6 >nul
copy tape13.out+tape11.out mk_i.u11 >nul
ren tape7.out mk_i.pch
ren tape15.out mk_i.dbg
ren tape16.out mk_i.vxs
ren tape50.out mk_i.ech
rem  cleanup files
del tape*.inp
del tape*.out
del *.pch
del *.vxs
del *.ech
del *.u11
del *.dbg
echo ************************************************************************************
echo ******************* O R I G E N 2 - Version 2.1 **********************
echo ********************** Execution Completed **************************
echo ************************************************************************************
echo on
```

DR WENZEL CONSULTING INC

1560 Mountain Rose

Radiological Consequence Analysis

Idaho Falls, Idaho 83402

ORIGEN2 run MK_I Summarized Output

	345.0D	35.0YR	36.0YR	37.0YR	38.0YR	39.0YR	40.0YR
H 3	1.593E-08	2.233E-09	2.111E-09	1.996E-09	1.887E-09	1.784E-09	1.687E-09
BE 10	1.550E-08	1.550E-08	1.550E-08	1.550E-08	1.550E-08	1.550E-08	1.550E-08
C 14	1.620E-08	1.613E-08	1.613E-08	1.613E-08	1.612E-08	1.612E-08	1.612E-08
NA 22	4.060E-15	3.624E-19	2.658E-19	1.950E-19	1.431E-19	1.050E-19	7.699E-20
SI 32	1.316E-11	1.267E-11	1.266E-11	1.265E-11	1.263E-11	1.262E-11	1.261E-11
P 32	1.638E+01	1.268E-11	1.266E-11	1.265E-11	1.264E-11	1.262E-11	1.261E-11
CL 36	8.307E-13	8.306E-13	8.306E-13	8.306E-13	8.306E-13	8.306E-13	8.306E-13
AR 39	1.638E-19	1.497E-19	1.493E-19	1.489E-19	1.485E-19	1.482E-19	1.478E-19
AR 42	6.682E-27	6.682E-27	6.682E-27	6.682E-27	6.682E-27	6.682E-27	6.682E-27
K 42	4.559E-18	6.682E-27	6.682E-27	6.682E-27	6.682E-27	6.682E-27	6.682E-27
V 50	1.328E-15	1.328E-15	1.328E-15	1.328E-15	1.328E-15	1.328E-15	1.328E-15
MN 54	5.469E+02	2.651E-10	1.179E-10	5.244E-11	2.333E-11	1.037E-11	4.615E-12
FE 55	3.245E+01	2.877E-03	2.203E-03	1.688E-03	1.293E-03	9.902E-04	7.585E-04
CO 60	2.677E-01	2.681E-03	2.351E-03	2.061E-03	1.807E-03	1.584E-03	1.389E-03
NI 59	4.101E-03	4.100E-03	4.100E-03	4.100E-03	4.100E-03	4.100E-03	4.100E-03
NI 63	5.438E-01	4.177E-01	4.146E-01	4.115E-01	4.084E-01	4.053E-01	4.023E-01
ZN 65	1.196E-11	1.984E-27	1.984E-27	1.984E-27	1.984E-27	1.984E-27	1.984E-27
SR 90	2.507E-09	1.090E-09	1.064E-09	1.039E-09	1.015E-09	9.910E-10	9.677E-10
Y 90	2.590E-02	1.090E-09	1.065E-09	1.040E-09	1.015E-09	9.912E-10	9.679E-10
ZR 93	8.792E-07	8.792E-07	8.792E-07	8.792E-07	8.792E-07	8.792E-07	8.792E-07
NB 93M	1.972E-08	6.983E-07	7.051E-07	7.115E-07	7.177E-07	7.235E-07	7.291E-07
NB 94	1.792E-05	1.789E-05	1.789E-05	1.789E-05	1.789E-05	1.789E-05	1.789E-05
MO 93	8.079E-04	8.023E-04	8.022E-04	8.020E-04	8.018E-04	8.017E-04	8.015E-04
TC 97	8.044E-07	8.146E-07	8.146E-07	8.146E-07	8.146E-07	8.146E-07	8.146E-07
TC 98	2.664E-11	2.664E-11	2.664E-11	2.664E-11	2.664E-11	2.664E-11	2.664E-11
TC 99	2.989E-04	3.024E-04	3.024E-04	3.024E-04	3.024E-04	3.024E-04	3.024E-04
RU106	1.321E-04	4.662E-15	2.344E-15	1.178E-15	5.924E-16	2.979E-16	1.498E-16
RH102	2.386E-02	5.554E-06	4.373E-06	3.444E-06	2.712E-06	2.135E-06	1.681E-06
RH106	4.249E-03	4.662E-15	2.344E-15	1.178E-15	5.924E-16	2.979E-16	1.498E-16
PD107	2.204E-11	2.204E-11	2.204E-11	2.204E-11	2.204E-11	2.204E-11	2.204E-11
AG108	3.296E-14	4.624E-20	4.598E-20	4.573E-20	4.548E-20	4.523E-20	4.499E-20
AG108M	6.289E-19	5.195E-19	5.167E-19	5.138E-19	5.110E-19	5.082E-19	5.055E-19
AG109M	4.137E-10	4.422E-27	4.422E-27	4.422E-27	4.422E-27	4.422E-27	4.422E-27
AG110	3.507E-13	6.172E-32	6.815E-32	6.815E-32	6.815E-32	6.815E-32	6.815E-32
AG110M	1.167E-14	4.641E-30	4.641E-30	4.641E-30	4.641E-30	4.641E-30	4.641E-30
CD109	8.694E-19	4.422E-27	4.422E-27	4.422E-27	4.422E-27	4.422E-27	4.422E-27
TL206	4.583E-24	4.583E-24	4.583E-24	4.583E-24	4.583E-24	4.583E-24	4.583E-24
TL207	1.458E-09	1.914E-06	2.009E-06	2.101E-06	2.194E-06	2.288E-06	2.384E-06
TL208	1.884E-06	9.737E-06	9.679E-06	9.586E-06	9.495E-06	9.404E-06	9.314E-06
TL209	5.544E-12	1.007E-10	1.034E-10	1.061E-10	1.088E-10	1.115E-10	1.142E-10
PB209	2.567E-10	4.661E-09	4.786E-09	4.911E-09	5.036E-09	5.161E-09	5.285E-09
PB210	6.686E-12	1.323E-07	1.427E-07	1.536E-07	1.650E-07	1.768E-07	1.892E-07
PB211	1.462E-09	1.920E-06	2.015E-06	2.107E-06	2.200E-06	2.295E-06	2.391E-06
PB212	5.243E-06	2.710E-05	2.694E-05	2.668E-05	2.643E-05	2.617E-05	2.592E-05
PB214	3.201E-10	4.594E-07	4.852E-07	5.118E-07	5.390E-07	5.670E-07	5.956E-07
BI208	1.181E-22	1.181E-22	1.181E-22	1.181E-22	1.181E-22	1.181E-22	1.181E-22
BI210M	4.601E-24	4.601E-24	4.601E-24	4.601E-24	4.601E-24	4.601E-24	4.601E-24
BI210	6.360E-12	1.323E-07	1.428E-07	1.537E-07	1.651E-07	1.769E-07	1.893E-07
BI211	1.462E-09	1.920E-06	2.015E-06	2.107E-06	2.200E-06	2.295E-06	2.391E-06
BI212	5.243E-06	2.710E-05	2.694E-05	2.668E-05	2.643E-05	2.617E-05	2.592E-05
BI213	2.567E-10	4.661E-09	4.786E-09	4.911E-09	5.036E-09	5.161E-09	5.285E-09
BI214	3.201E-10	4.594E-07	4.852E-07	5.118E-07	5.390E-07	5.670E-07	5.956E-07
PO210	2.233E-12	1.323E-07	1.365E-07	1.461E-07	1.569E-07	1.683E-07	1.803E-07
PO211	4.093E-12	5.375E-09	5.641E-09	5.899E-09	6.160E-09	6.425E-09	6.693E-09
PO212	3.359E-06	1.736E-05	1.726E-05	1.709E-05	1.693E-05	1.677E-05	1.661E-05
PO213	2.511E-10	4.561E-09	4.683E-09	4.805E-09	4.927E-09	5.049E-09	5.171E-09
PO214	5.947E-10	4.593E-07	4.851E-07	5.117E-07	5.389E-07	5.669E-07	5.955E-07
PO215	1.462E-09	1.920E-06	2.015E-06	2.107E-06	2.200E-06	2.295E-06	2.391E-06
PO216	5.243E-06	2.710E-05	2.694E-05	2.668E-05	2.643E-05	2.617E-05	2.592E-05
PO218	3.202E-10	4.595E-07	4.853E-07	5.119E-07	5.391E-07	5.671E-07	5.958E-07
AT217	2.567E-10	4.661E-09	4.786E-09	4.911E-09	5.036E-09	5.161E-09	5.285E-09

ORIGEN2 run MK_I Summarized Output (Continued)

	345.0D	35.0YR	36.0YR	37.0YR	38.0YR	39.0YR	40.0YR
RN219	1.462E-09	1.920E-06	2.015E-06	2.107E-06	2.200E-06	2.295E-06	2.391E-06
RN220	5.243E-06	2.710E-05	2.694E-05	2.668E-05	2.643E-05	2.617E-05	2.592E-05
RN222	3.202E-10	4.595E-07	4.853E-07	5.119E-07	5.391E-07	5.671E-07	5.958E-07
FR221	2.567E-10	4.661E-09	4.786E-09	4.911E-09	5.036E-09	5.161E-09	5.285E-09
FR223	2.599E-11	2.649E-08	2.774E-08	2.901E-08	3.030E-08	3.160E-08	3.292E-08
RA223	1.462E-09	1.920E-06	2.015E-06	2.107E-06	2.200E-06	2.295E-06	2.391E-06
RA224	5.243E-06	2.710E-05	2.694E-05	2.668E-05	2.643E-05	2.617E-05	2.592E-05
RA225	2.804E-10	4.661E-09	4.786E-09	4.911E-09	5.036E-09	5.161E-09	5.285E-09
RA226	3.201E-10	4.595E-07	4.853E-07	5.119E-07	5.391E-07	5.671E-07	5.957E-07
RA228	1.408E-15	1.577E-12	1.635E-12	1.694E-12	1.753E-12	1.813E-12	1.872E-12
AC225	2.567E-10	4.661E-09	4.786E-09	4.911E-09	5.036E-09	5.161E-09	5.285E-09
AC227	1.883E-09	1.920E-06	2.010E-06	2.102E-06	2.195E-06	2.290E-06	2.385E-06
AC228	1.957E-10	1.577E-12	1.636E-12	1.694E-12	1.753E-12	1.813E-12	1.872E-12
TH227	1.593E-09	1.893E-06	1.987E-06	2.078E-06	2.170E-06	2.263E-06	2.358E-06
TH228	5.222E-06	2.710E-05	2.684E-05	2.658E-05	2.633E-05	2.608E-05	2.583E-05
TH229	3.121E-10	4.661E-09	4.786E-09	4.911E-09	5.036E-09	5.160E-09	5.285E-09
TH230	1.564E-06	5.931E-05	6.096E-05	6.261E-05	6.426E-05	6.591E-05	6.756E-05
TH231	6.521E-03	6.239E-03	6.239E-03	6.239E-03	6.239E-03	6.239E-03	6.239E-03
TH232	3.644E-14	2.144E-12	2.204E-12	2.264E-12	2.325E-12	2.385E-12	2.445E-12
TH234	8.833E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04
PA231	1.265E-07	4.745E-06	4.877E-06	5.010E-06	5.142E-06	5.274E-06	5.407E-06
PA233	7.858E-05	9.200E-05	9.200E-05	9.200E-05	9.200E-05	9.200E-05	9.200E-05
PA234M	8.833E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04
PA234	1.186E-06	1.148E-06	1.148E-06	1.148E-06	1.148E-06	1.148E-06	1.148E-06
U232	3.439E-05	2.638E-05	2.613E-05	2.588E-05	2.563E-05	2.538E-05	2.514E-05
U233	1.311E-06	1.325E-06	1.326E-06	1.326E-06	1.326E-06	1.327E-06	1.327E-06
U234	1.833E-01	1.833E-01	1.833E-01	1.833E-01	1.833E-01	1.833E-01	1.833E-01
U235	6.239E-03	6.239E-03	6.239E-03	6.239E-03	6.239E-03	6.239E-03	6.239E-03
U236	1.221E-03	1.221E-03	1.221E-03	1.221E-03	1.221E-03	1.221E-03	1.221E-03
U237	3.746E+02	1.152E-08	1.098E-08	1.046E-08	9.973E-09	9.504E-09	9.057E-09
U238	8.830E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04	8.830E-04
U240	1.680E-04	1.075E-21	1.075E-21	1.075E-21	1.075E-21	1.075E-21	1.075E-21
NP235	2.147E-06	4.126E-16	2.178E-16	1.149E-16	6.062E-17	3.198E-17	1.690E-17
NP236	1.190E-09	1.190E-09	1.190E-09	1.190E-09	1.190E-09	1.190E-09	1.190E-09
NP237	8.876E-05	9.200E-05	9.200E-05	9.200E-05	9.200E-05	9.200E-05	9.200E-05
NP238	3.578E+00	6.869E-12	6.838E-12	6.807E-12	6.776E-12	6.745E-12	6.714E-12
NP239	1.841E+04	3.787E-12	3.786E-12	3.786E-12	3.786E-12	3.785E-12	3.785E-12
NP240M	3.427E-02	1.075E-21	1.075E-21	1.075E-21	1.075E-21	1.075E-21	1.075E-21
PU236	6.137E-05	1.259E-08	9.899E-09	7.786E-09	6.129E-09	4.829E-09	3.810E-09
PU238	1.216E-02	9.404E-03	9.330E-03	9.256E-03	9.184E-03	9.111E-03	9.040E-03
PU239	4.874E-01	4.919E-01	4.919E-01	4.918E-01	4.918E-01	4.918E-01	4.918E-01
PU240	3.667E-03	3.654E-03	3.653E-03	3.653E-03	3.653E-03	3.652E-03	3.652E-03
PU241	2.532E-03	4.697E-04	4.476E-04	4.266E-04	4.065E-04	3.874E-04	3.692E-04
PU242	9.245E-11	9.246E-11	9.246E-11	9.246E-11	9.246E-11	9.246E-11	9.246E-11
PU244	1.076E-21	1.076E-21	1.076E-21	1.076E-21	1.076E-21	1.076E-21	1.076E-21
AM241	9.643E-07	6.723E-05	6.786E-05	6.845E-05	6.901E-05	6.953E-05	7.003E-05
AM242M	1.611E-09	1.374E-09	1.368E-09	1.361E-09	1.355E-09	1.349E-09	1.343E-09
AM242	7.482E-06	1.367E-09	1.361E-09	1.354E-09	1.348E-09	1.342E-09	1.336E-09
AM243	3.783E-12	3.787E-12	3.786E-12	3.786E-12	3.786E-12	3.785E-12	3.785E-12
CM242	1.446E-06	1.130E-09	1.127E-09	1.122E-09	1.117E-09	1.112E-09	1.107E-09
CM243	9.655E-12	4.122E-12	4.023E-12	3.926E-12	3.832E-12	3.740E-12	3.650E-12
CM244	2.177E-12	5.708E-13	5.494E-13	5.288E-13	5.089E-13	4.898E-13	4.714E-13
CM245	4.713E-18	4.700E-18	4.699E-18	4.699E-18	4.699E-18	4.698E-18	4.698E-18
CM246	2.794E-21	2.780E-21	2.780E-21	2.780E-21	2.780E-21	2.780E-21	2.780E-21
H 3	1.282E+00	1.798E-01	1.700E-01	1.607E-01	1.519E-01	1.436E-01	1.358E-01
BE 10	4.552E-09	4.552E-09	4.552E-09	4.552E-09	4.552E-09	4.552E-09	4.552E-09
C 14	1.836E-07	1.828E-07	1.828E-07	1.828E-07	1.828E-07	1.828E-07	1.827E-07
SE 79	8.428E-04	8.425E-04	8.425E-04	8.425E-04	8.425E-04	8.425E-04	8.425E-04
KR 81	7.632E-12	7.631E-12	7.631E-12	7.631E-12	7.631E-12	7.631E-12	7.631E-12
KR 85	1.978E+01	2.060E+00	1.931E+00	1.810E+00	1.696E+00	1.590E+00	1.491E+00
RB 87	4.227E-08	4.228E-08	4.228E-08	4.228E-08	4.228E-08	4.228E-08	4.228E-08

L. S. Cahn
March 22, 2005
Attachment 3

ORIGEN2 run MK_I Summarized Output (Continued)

	345.0D	35.0YR	36.0YR	37.0YR	38.0YR	39.0YR	40.0YR
SR 90	1.467E+02	6.378E+01	6.228E+01	6.081E+01	5.938E+01	5.799E+01	5.662E+01
Y 90	1.480E+02	6.380E+01	6.230E+01	6.083E+01	5.940E+01	5.800E+01	5.664E+01
ZR 93	3.281E-03	3.286E-03	3.286E-03	3.286E-03	3.286E-03	3.286E-03	3.286E-03
NB 93M	7.419E-05	2.610E-03	2.635E-03	2.660E-03	2.683E-03	2.704E-03	2.725E-03
NB 94	2.700E-08	2.697E-08	2.696E-08	2.696E-08	2.696E-08	2.696E-08	2.696E-08
TC 98	1.892E-09	1.892E-09	1.892E-09	1.892E-09	1.892E-09	1.892E-09	1.892E-09
TC 99	2.117E-02	2.144E-02	2.144E-02	2.144E-02	2.144E-02	2.144E-02	2.144E-02
RH102	4.201E-04	9.778E-08	7.699E-08	6.063E-08	4.774E-08	3.759E-08	2.960E-08
RU106	3.985E+02	1.406E-08	7.068E-09	3.553E-09	1.787E-09	8.982E-10	4.516E-10
RH106	3.985E+02	1.406E-08	7.068E-09	3.553E-09	1.787E-09	8.982E-10	4.516E-10
PD107	5.552E-05	5.553E-05	5.553E-05	5.553E-05	5.553E-05	5.553E-05	5.553E-05
AG108	7.006E-04	2.221E-11	2.209E-11	2.197E-11	2.185E-11	2.173E-11	2.161E-11
AG108M	3.021E-10	2.496E-10	2.482E-10	2.469E-10	2.455E-10	2.442E-10	2.429E-10
AG109M	2.420E+02	4.520E-16	2.619E-16	1.518E-16	8.794E-17	5.096E-17	2.955E-17
CD109	8.887E-08	4.520E-16	2.619E-16	1.518E-16	8.793E-17	5.095E-17	2.954E-17
AG110	9.773E-01	4.192E-19	1.522E-19	5.505E-20	2.033E-20	7.536E-21	2.736E-21
AG110M	7.922E-02	3.152E-17	1.140E-17	4.124E-18	1.529E-18	5.666E-19	1.852E-19
CD113M	9.267E-02	1.758E-02	1.677E-02	1.599E-02	1.525E-02	1.454E-02	1.386E-02
IN115	1.478E-13	1.519E-13	1.519E-13	1.519E-13	1.519E-13	1.519E-13	1.519E-13
SN119M	1.086E+00	2.138E-16	7.606E-17	2.708E-17	9.597E-18	3.401E-18	1.239E-18
SN121M	7.095E-04	4.366E-04	4.306E-04	4.247E-04	4.188E-04	4.131E-04	4.074E-04
TE123	1.529E-17	1.675E-17	1.675E-17	1.675E-17	1.675E-17	1.675E-17	1.675E-17
SB125	4.065E+01	6.476E-03	5.042E-03	3.926E-03	3.057E-03	2.380E-03	1.853E-03
TE125M	7.238E+00	1.580E-03	1.230E-03	9.578E-04	7.458E-04	5.807E-04	4.521E-04
SN126	1.846E-03	1.845E-03	1.845E-03	1.845E-03	1.845E-03	1.845E-03	1.845E-03
SB126	4.999E+00	2.584E-04	2.584E-04	2.584E-04	2.583E-04	2.583E-04	2.583E-04
SB126M	3.671E+00	1.845E-03	1.845E-03	1.845E-03	1.845E-03	1.845E-03	1.845E-03
I129	5.679E-05	5.799E-05	5.799E-05	5.799E-05	5.799E-05	5.799E-05	5.799E-05
CS134	4.841E+00	3.760E-05	2.687E-05	1.920E-05	1.372E-05	9.801E-06	7.003E-06
CS135	2.194E-03	2.200E-03	2.200E-03	2.200E-03	2.200E-03	2.200E-03	2.200E-03
CS137	1.588E+02	7.075E+01	6.914E+01	6.756E+01	6.602E+01	6.451E+01	6.303E+01
BA137M	1.508E+02	6.693E+01	6.540E+01	6.391E+01	6.245E+01	6.102E+01	5.963E+01
LA138	1.610E-13	1.610E-13	1.610E-13	1.610E-13	1.610E-13	1.610E-13	1.610E-13
CE142	4.216E-08	4.218E-08	4.218E-08	4.218E-08	4.218E-08	4.218E-08	4.218E-08
CE144	3.610E+03	1.046E-10	4.293E-11	1.762E-11	7.231E-12	2.968E-12	1.218E-12
PR144	3.612E+03	1.046E-10	4.294E-11	1.762E-11	7.231E-12	2.968E-12	1.218E-12
PR144M	4.337E+01	1.255E-12	5.152E-13	2.114E-13	8.677E-14	3.561E-14	1.461E-14
ND144	6.437E-13	1.983E-12	1.983E-12	1.983E-12	1.983E-12	1.983E-12	1.983E-12
PM146	2.237E-03	2.717E-05	2.395E-05	2.112E-05	1.862E-05	1.641E-05	1.447E-05
SM146	3.414E-11	9.839E-11	9.848E-11	9.856E-11	9.864E-11	9.870E-11	9.876E-11
PM147	6.011E+02	6.116E-02	4.696E-02	3.606E-02	2.769E-02	2.126E-02	1.632E-02
SM147	1.829E-09	1.738E-08	1.738E-08	1.738E-08	1.738E-08	1.738E-08	1.738E-08
SM148	1.952E-15	2.388E-15	2.388E-15	2.388E-15	2.388E-15	2.388E-15	2.388E-15
SM149	8.672E-14	8.756E-14	8.756E-14	8.756E-14	8.756E-14	8.756E-14	8.756E-14
EU150	7.807E-08	3.979E-08	3.903E-08	3.829E-08	3.756E-08	3.684E-08	3.614E-08
SM151	3.904E+00	2.997E+00	2.974E+00	2.951E+00	2.928E+00	2.906E+00	2.884E+00
EU152	9.215E-04	1.548E-04	1.471E-04	1.398E-04	1.329E-04	1.263E-04	1.200E-04
GD152	4.496E-17	7.208E-17	7.235E-17	7.261E-17	7.285E-17	7.309E-17	7.331E-17
GD153	6.165E-05	7.741E-21	7.741E-21	7.741E-21	7.741E-21	7.741E-21	7.741E-21
EU154	1.639E-01	9.761E-03	9.005E-03	8.308E-03	7.664E-03	7.071E-03	6.523E-03
EU155	8.825E+00	6.625E-02	5.761E-02	5.009E-02	4.356E-02	3.788E-02	3.294E-02
HO166M	4.052E-08	3.971E-08	3.969E-08	3.966E-08	3.964E-08	3.962E-08	3.960E-08
TM171	3.173E-14	1.033E-19	6.598E-20	4.216E-20	4.216E-20	4.216E-20	4.216E-20

ORIGEN2 run AL1 Input

```
-1
-1
-1
  RDA     ORIGEN2, VERSION 2.1 (8-1-91) ATR
  TIT     THREE CYCLES WITN 48.74% BURNUP
  BAS     ONE ATR ELEMENT
  CUT     -1
  LIP     0 0 0
  LIB     0  1 2 3  0  205  206   9   0   0  1  1
  PHO     101  102  103  10
  INP     -1   1  -1  -1  1  1
  MOV     -1   1   0   1.0
  HED      1                                                    ELEMENT
  BUP
  IRP      2.5   10.0   1   2   4 2
  IRP      5.0   10.0   2   3   4 0
  IRP      7.5   10.0   3   4   4 0
  IRP     10.0   10.0   4   5   4 0
  IRP     12.5   10.0   5   6   4 0
  IRP     15.0   10.0   6   7   4 0
  DEC     30.0          7   8   4 0
  MOV      8    1    0    1.0
  IRP     35.0    6.5   8   1   4 0
  IRP     40.0    6.5   1   2   4 0
  IRP     45.0    6.5   2   3   4 0
  IRP     50.0    6.5   3   4   4 0
  IRP     55.0    6.5   4   5   4 0
  IRP     60.0    6.5   5   6   4 0
  DEC     90.0          6   7   4 0
  MOV      7    1    0    1.0
  IRP     95.0   2.176   7   1   4 0
  IRP    100.0   2.176   1   2   4 0
  IRP    105.0   2.176   2   3   4 0
  IRP    110.0   2.176   3   4   4 0
  IRP    115.0   2.176   4   5   4 0
  IRP    120.0   2.176   5   6   4 0
  BUP
  OPTL    8 8 8 8 5   8 5 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTA    8 8 8 8 5   8 5 8 5 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  OPTF    8 8 8 8 5   8 5 8 5 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
  MOV      6    1    0    1.0
  DEC       6.    1   2   5   4
  OUT      -2     1     -1    0
  OUT       2     1     -1    0
  END
  2   922350  1073. 922360  3.368  922380  74.62  0    0.0   FUEL 93.2%
  0
```

1560 Mountain Rose
Idaho Falls, Idaho 83402

ORIGEN2 run AL1 BAT File

```
echo off
echo **                                                                  **
echo **                         O R I G E N 2                            **
echo **                                                                  **
copy al1.INP tape5.inp >nul
REM  (NOT USED IN THIS CASE) copy al1.u3 tape3.inp >nul
copy \origen2\libs\decay.lib+\origen2\libs\pwru.lib tape9.inp >nul
copy \origen2\libs\gxuo2brm.lib tape10.inp >nul
\origen2\code\origen2
echo finished with origen2 calculation
rem  combine and save files from run
copy tape12.out+tape6.out al1.u6 >nul
copy tape13.out+tape11.out al1.u11 >nul
ren tape7.out al1.pch
ren tape15.out al1.dbg
ren tape16.out al1.vxs
ren tape50.out al1.ech
rem  cleanup files
del tape*.inp
del tape*.out
echo ***********************************************************************
echo ****************** O R I G E N 2 - Version 2.1 **********************
echo ********************** Execution Completed **************************
echo ***********************************************************************
echo on
```

ORIGEN2 run AL1 Summarized Output

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
HE 4	5.336E-06	3.121E-04
TL206	4.338E-33	4.338E-33
TL207	1.196E-19	7.856E-17
TL208	1.344E-16	6.347E-14
TL209	1.014E-21	3.361E-21
PB206	3.922E-19	9.556E-16
PB207	8.408E-16	1.268E-11
PB208	3.624E-12	5.796E-08
PB209	4.229E-18	1.400E-17
PB210	1.768E-15	1.267E-14
PB211	9.249E-19	6.077E-16
PB212	7.929E-14	3.744E-11
PB214	3.890E-22	3.909E-19
BI208	2.746E-22	2.746E-22
BI209	4.052E-16	7.319E-14
BI210M	1.672E-21	1.672E-21
BI210	8.819E-19	7.798E-18
BI211	5.457E-20	3.586E-17
BI212	7.521E-15	3.551E-12
BI213	9.931E-19	3.290E-18
BI214	2.889E-22	2.903E-19
PO210	3.305E-18	2.154E-16

ORIGEN2 run AL1 Summarized Output (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
PO211	6.695E-25	4.399E-22
PO212	3.979E-25	1.879E-22
PO213	1.490E-27	4.936E-27
PO214	1.667E-25	3.993E-26
PO215	7.742E-25	5.089E-22
PO216	3.163E-19	1.494E-16
PO218	4.511E-23	4.533E-20
AT217	1.193E-23	3.953E-23
RN219	1.755E-21	1.153E-18
RN220	1.194E-16	5.640E-14
RN222	8.292E-20	8.334E-17
FR221	1.083E-19	3.590E-19
FR223	1.564E-20	5.352E-18
RA223	4.457E-16	2.929E-13
RA224	6.913E-13	3.266E-10
RA225	8.339E-16	1.623E-15
RA226	1.444E-14	1.296E-11
RA228	3.799E-18	2.104E-15
AC225	3.309E-16	1.096E-15
AC227	6.061E-13	2.074E-10
AC228	9.139E-16	2.196E-19
TH227	9.740E-16	4.814E-13
TH228	1.521E-10	6.347E-08
TH229	1.642E-11	2.991E-10
TH230	1.254E-08	5.252E-07
TH231	2.292E-09	2.236E-09
TH232	6.093E-07	1.710E-05
TH234	1.042E-09	1.074E-09
PA231	1.718E-07	3.369E-06
PA233	8.460E-08	1.418E-07
PA234M	1.407E-13	3.620E-14
PA234	3.609E-11	1.617E-14
U232	1.663E-07	3.466E-06
U233	6.963E-06	1.488E-05
U234	2.174E-02	3.945E-02
U235	5.500E+02	5.500E+02
U236	9.442E+01	9.442E+01
U237	5.235E-01	7.445E-10
U238	7.395E+01	7.395E+01
U240	3.690E-08	3.515E-18
NP235	2.524E-08	5.451E-10
NP236	2.209E-06	2.209E-06
NP237	3.651E+00	4.174E+00
NP238	2.906E-02	4.714E-13
NP239	1.951E-02	2.682E-10
NP240M	3.590E-08	3.075E-20
PU236	4.385E-06	1.056E-06

ORIGEN2 run AL1 Summarized Output (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
PU237	1.558E-07	5.312E-22
PU238	3.599E-01	3.710E-01
PU239	3.728E-01	3.923E-01
PU240	1.048E-01	1.047E-01
PU241	3.210E-02	2.404E-02
PU242	4.110E-03	4.110E-03
PU243	3.331E-06	3.682E-21
PU244	1.838E-07	1.838E-07
PU246	1.856E-13	5.248E-27
AM241	1.636E-04	8.173E-03
AM242M	2.584E-06	2.514E-06
AM242	1.437E-06	3.008E-11
AM243	3.089E-04	3.120E-04
AM245	2.356E-12	3.689E-25
AM246	2.972E-16	8.397E-30
CM241	1.873E-12	8.858E-31
CM242	3.004E-05	8.914E-09
CM243	2.454E-07	2.120E-07
CM244	3.212E-05	2.559E-05
CM245	6.044E-07	6.042E-07
CM246	2.739E-08	2.736E-08
CM247	1.033E-10	1.033E-10
CM248	2.058E-12	2.058E-12
CM250	1.248E-20	1.250E-20
BK249	1.098E-14	9.591E-17
BK250	4.218E-17	5.720E-27
CF249	2.724E-16	1.112E-14
CF250	1.485E-15	1.111E-15
CF251	3.812E-16	3.795E-16
CF252	9.024E-17	1.865E-17
CF254	3.935E-21	4.906E-32
ES254	2.928E-21	4.113E-24
ES255	3.219E-25	7.504E-42
SF250	1.033E-12	5.086E-11
H 3	5.950E-04	4.249E-04
LI 6	3.334E-06	3.334E-06
LI 7	1.275E-07	1.275E-07
BE 9	2.456E-07	2.456E-07
BE 10	1.639E-06	1.639E-06
C 14	3.314E-07	3.311E-07
ZN 66	6.515E-10	6.516E-10
ZN 67	2.896E-11	2.896E-11
ZN 68	1.972E-13	1.972E-13
GA 69	1.357E-16	1.360E-16
GE 70	2.128E-19	2.129E-19

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ORIGEN2 run AL1 Summarized Output (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
GA 71	7.335E-09	7.335E-09
GE 72	9.013E-05	9.190E-05
GE 73	3.237E-04	3.242E-04
GE 74	8.689E-04	8.690E-04
AS 75	2.094E-03	2.095E-03
GE 76	6.349E-03	6.349E-03
SE 76	2.788E-05	2.850E-05
SE 77	1.397E-02	1.416E-02
SE 78	2.974E-02	2.977E-02
SE 79	7.618E-02	7.618E-02
BR 79	1.771E-07	5.055E-06
SE 80	1.835E-01	1.835E-01
KR 80	8.850E-07	8.856E-07
BR 81	3.088E-01	3.089E-01
KR 81	2.667E-08	2.667E-08
SE 82	4.967E-01	4.967E-01
KR 82	6.059E-03	6.235E-03
KR 83	7.109E-01	7.121E-01
KR 84	1.678E+00	1.678E+00
KR 85	4.135E-01	2.810E-01
RB 85	1.555E+00	1.690E+00
KR 86	3.153E+00	3.153E+00
SR 86	2.153E-03	2.885E-03
RB 87	4.076E+00	4.077E+00
SR 87	9.276E-06	9.283E-06
SR 88	5.877E+00	5.882E+00
SR 89	2.943E+00	2.540E-13
Y 89	4.812E+00	7.756E+00
SR 90	9.332E+00	8.090E+00
Y 90	2.505E-03	2.029E-03
ZR 90	6.205E-02	1.304E+00
Y 91	4.135E+00	2.208E-11
ZR 91	5.561E+00	9.726E+00
ZR 92	1.004E+01	1.006E+01
ZR 93	1.084E+01	1.087E+01
NB 93	7.499E-08	5.709E-06
NB 93M	1.021E-06	2.495E-05
ZR 94	1.075E+01	1.075E+01
NB 94	1.467E-06	1.467E-06
ZR 95	5.051E+00	2.469E-10
NB 95	2.508E+00	3.011E-10
NB 95M	1.992E-03	1.033E-13
MO 95	3.473E+00	1.103E+01
ZR 96	1.101E+01	1.101E+01
MO 96	5.233E-02	5.259E-02
MO 97	1.048E+01	1.054E+01

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ORIGEN2 run AL1 Summarized Output (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
MO 98	1.047E+01	1.047E+01
TC 98	3.787E-05	3.787E-05
TC 99	1.034E+01	1.059E+01
RU 99	7.140E-06	2.138E-04
MO100	1.146E+01	1.146E+01
RU100	5.743E-01	5.743E-01
RU101	9.188E+00	9.189E+00
RU102	8.041E+00	8.041E+00
RH102	3.175E-06	7.566E-07
RU103	1.772E+00	2.849E-17
RH103	3.518E+00	5.293E+00
RH103M	1.585E-03	2.548E-20
RU104	3.639E+00	3.639E+00
PD104	5.863E-01	5.863E-01
PD105	1.283E+00	1.302E+00
RU106	7.004E-01	1.131E-02
RH106	1.405E-06	1.063E-08
PD106	8.512E-01	1.540E+00
PD107	3.756E-01	3.757E-01
AG107	8.510E-09	2.490E-07
PD108	1.817E-01	1.817E-01
AG108	7.712E-12	1.507E-19
AG108M	4.933E-11	4.774E-11
CD108	2.424E-07	2.424E-07
AG109	7.770E-02	7.820E-02
AG109M	4.004E-07	7.848E-18
CD109	2.098E-10	7.945E-12
PD110	6.624E-02	6.624E-02
AG110	1.076E-07	3.029E-14
AG110M	8.718E-04	1.999E-06
CD110	1.995E-02	2.082E-02
CD111	5.001E-02	5.297E-02
CD112	4.158E-02	4.187E-02
CD113	5.653E-04	6.227E-04
CD113M	8.265E-04	6.221E-04
IN113	7.952E-06	2.129E-04
CD114	7.397E-02	7.397E-02
IN114	7.225E-12	6.684E-26
IN114M	8.757E-08	4.156E-21
SN114	2.171E-07	2.981E-07
CD115M	1.007E-03	1.621E-18
IN115	1.365E-02	1.522E-02
IN115M	4.397E-05	4.577E-25
SN115	1.132E-03	1.153E-03
CD116	3.582E-02	3.582E-02
SN116	1.873E-02	1.874E-02

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ORIGEN2 run AL1 Summarized Output (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
SN117	3.506E-02	3.512E-02
SN118	3.919E-02	3.920E-02
SN119	3.705E-02	3.753E-02
SN119M	4.722E-04	9.615E-07
SN120	3.930E-02	3.930E-02
SN121M	1.942E-05	1.787E-05
SB121	3.991E-02	4.027E-02
SN122	4.405E-02	4.405E-02
TE122	1.262E-03	1.332E-03
SN123	8.486E-03	6.627E-08
SB123	4.335E-02	5.184E-02
TE123	8.045E-06	1.128E-05
TE123M	3.232E-06	9.932E-12
SN124	6.889E-02	6.889E-02
SB124	5.260E-04	5.779E-15
TE124	4.058E-04	9.319E-04
SB125	8.363E-02	1.918E-02
TE125	3.819E-03	7.108E-02
TE125M	6.318E-04	2.682E-04
SN126	1.663E-01	1.663E-01
SB126	2.728E-04	7.899E-09
SB126M	1.256E-07	6.006E-11
TE126	3.471E-03	3.750E-03
TE127	1.094E-03	1.020E-10
TE127M	3.126E-02	2.913E-08
I127	3.260E-01	3.693E-01
XE127	8.082E-09	6.161E-27
TE128	9.310E-01	9.314E-01
XE128	8.421E-03	8.424E-03
TE129	5.858E-04	1.344E-24
TE129M	6.155E-02	1.435E-21
I129	1.567E+00	1.632E+00
XE129	2.171E-05	2.247E-05
TE130	3.578E+00	3.578E+00
XE130	5.178E-02	5.228E-02
XE131	5.530E+00	5.942E+00
XE132	1.116E+01	1.142E+01
BA132	8.641E-06	9.917E-06
CS133	1.447E+01	1.522E+01
XE134	1.909E+01	1.910E+01
CS134	8.547E-01	1.138E-01
BA134	4.086E-02	7.821E-01
CS135	1.005E+00	1.041E+00
BA135	8.660E-05	8.883E-05
XE136	3.120E+01	3.120E+01
BA136	2.651E-02	3.106E-02

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ORIGEN2 run AL1 Summarized Output (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
CS137	1.519E+01	1.323E+01
BA137	7.741E-02	2.044E+00
BA137M	2.333E-06	2.023E-06
BA138	1.709E+01	1.710E+01
LA138	1.249E-04	1.249E-04
LA139	1.623E+01	1.624E+01
CE140	1.435E+01	1.593E+01
CE141	3.720E+00	1.912E-20
PR141	1.120E+01	1.494E+01
CE142	1.534E+01	1.534E+01
ND142	8.771E-02	8.983E-02
ND143	1.193E+01	1.350E+01
CE144	1.175E+01	5.610E-02
PR144	5.215E-04	2.369E-06
PR144M	2.483E-06	1.184E-08
ND144	4.509E+00	1.620E+01
ND145	9.725E+00	9.745E+00
ND146	8.497E+00	8.498E+00
PM146	6.090E-05	2.859E-05
SM146	4.404E-06	1.636E-05
PM147	3.344E+00	7.809E-01
SM147	1.853E-01	3.216E+00
ND148	4.733E+00	4.733E+00
PM148	7.767E-02	2.696E-20
PM148M	3.475E-02	3.681E-18
SM148	6.330E-01	7.454E-01
SM149	4.994E-02	1.509E-01
ND150	1.770E+00	1.770E+00
SM150	3.837E+00	3.837E+00
EU150	5.764E-10	5.135E-10
SM151	1.799E-01	1.818E-01
EU151	6.089E-05	8.660E-03
SM152	1.394E+00	1.394E+00
EU152	1.951E-04	1.437E-04
GD152	6.130E-05	7.627E-05
EU153	7.797E-01	8.111E-01
GD153	4.227E-05	7.948E-08
SM154	2.531E-01	2.531E-01
EU154	1.899E-01	1.171E-01
GD154	2.152E-03	7.498E-02
EU155	6.279E-02	2.715E-02
GD155	1.083E-04	3.576E-02
GD156	1.270E-01	1.590E-01
GD157	3.528E-04	6.437E-04
GD158	5.694E-02	5.694E-02
TB159	4.059E-03	4.093E-03

ORIGEN2 run AL1 Summarized Output (Continued)

ORIGEN2 V2.1 (8-1-91), Run on 02/08/05 at 16:28:09

	120.0D	6.0YR
GD160	1.555E-03	1.555E-03
TB160	1.885E-04	1.416E-13
DY160	1.020E-04	2.905E-04
DY161	3.395E-04	3.723E-04
DY162	2.497E-04	2.497E-04
DY163	1.414E-04	1.414E-04
DY164	2.030E-05	2.030E-05
HO165	4.886E-05	4.895E-05
HO166M	2.881E-07	2.871E-07
ER166	1.294E-05	1.340E-05
ER167	1.636E-06	1.636E-06
ER168	2.923E-06	2.923E-06
TM169	9.949E-09	1.278E-08
ER170	2.911E-13	2.031E-12
TM170	1.192E-09	8.826E-15
YB170	1.966E-10	1.387E-09
TM171	4.719E-11	5.409E-12
YB171	4.113E-12	4.589E-11
YB172	3.207E-13	3.645E-13